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2

System Requirements Review for the High-Resolution Ozone Imager (HIROIG)

15 September 1993

Prepared by

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Prepared for

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Development Group

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El Segundo, California

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This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

John R. Edwards

JOHN R. EDWARDS, Project Officer
SMC/CEV

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13. ABSTRACT (*Maximum 200 words*)

The HIROIG System Requirements Review was held on February 17, 1993 at The Aerospace Corporation. The purpose of the review was to demonstrate the way in which the requirements for a spaceborne ozone imaging experiment are derived from the fundamental goal of the program, which is to measure how space-vehicle launches affect the ozone layer of the atmosphere. The review included, towards the end, short presentations on the experiment team's approaches to meeting the program requirements. This report is a compilation of the briefing charts that were presented at the review.

14. SUBJECT TERMS
Ozone depletion, Launch vehicles, UV imaging spectrograph

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INTRODUCTION

D. L. McKENZIE

HIROIG

HIGH RESOLUTION OZONE IMAGER

PROBLEM

- UP TO 30% OF SOLID ROCKET MOTOR EXHAUST IS CHLORINE
  - LOCAL OZONE DEPLETION BY CHLORINE
  - KNOWLEDGE OF OZONE DEPLETION BY SRM LAUNCHES IS REQUIRED FOR DoD TO COMPLY WITH FEDERAL ENVIRONMENTAL LAWS
  - MEASUREMENT OF OZONE DEPLETION REQUIRES A UV SPECTROMETER HAVING UNPRECEDENTED SPATIAL RESOLUTION AND THE ABILITY TO MEASURE THE POLARIZATION OF BACKSCATTERED SUNLIGHT: HIROIG

PLANS FOR FY 1993

- CONSTRUCT TWO GROUND-BASED PROTOTYPE INSTRUMENTS
  - PRISM SPECTROMETER
  - GRATING SPECTROMETER
- PREPARE FOR PRELIMINARY DESIGN REVIEW IN OCTOBER 1993

PERSONNEL

SCIENCE TEAM

- DAVID McKENZIE - FLIGHT INSTRUMENT DEVELOPMENT
- JIM HECHT - INSTRUMENT DEVELOPMENT
- MARTY ROSS - THEORY
- GEORGE ROSSANO - INSTRUMENT DEVELOPMENT
- DAVID GORNEY - DIRECTOR, ATMOSPHERIC & IONOSPHERIC SCIENCES DEPARTMENT

ENGINEERING

- JOSEF STEIN - PROGRAM MANAGER
- DAVID GUTIERREZ - OPTICAL DESIGN
- MAZAHER SIVJEE - MECHANICAL DESIGN
- JIM SKINNER - MECHANICAL DESIGN
- NORM KATZ - DETECTOR ELECTRONICS
- DAN MABRY - DATA PROCESSING UNIT
- JON OSBORN - ELECTRONICS DESIGN
- KIRK CRAWFORD - SOFTWARE
- PATTY LIU - DETECTOR ELECTRONICS (USC INTERN)

AGENDA

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SCIENCE OVERVIEW	ROSS (10)
INSTRUMENT REQUIREMENTS	HECHT (15)
OPTICAL DESIGN	GUTIERREZ (10)/ROSSANO (5)
MECHANICAL DESIGN	SIVJEE (5)
DATA PROCESSING UNIT	MABRY (5)
MANAGEMENT AND SCHEDULES	STEIN (5)

SCIENCE OVERVIEW

M. N. ROSS

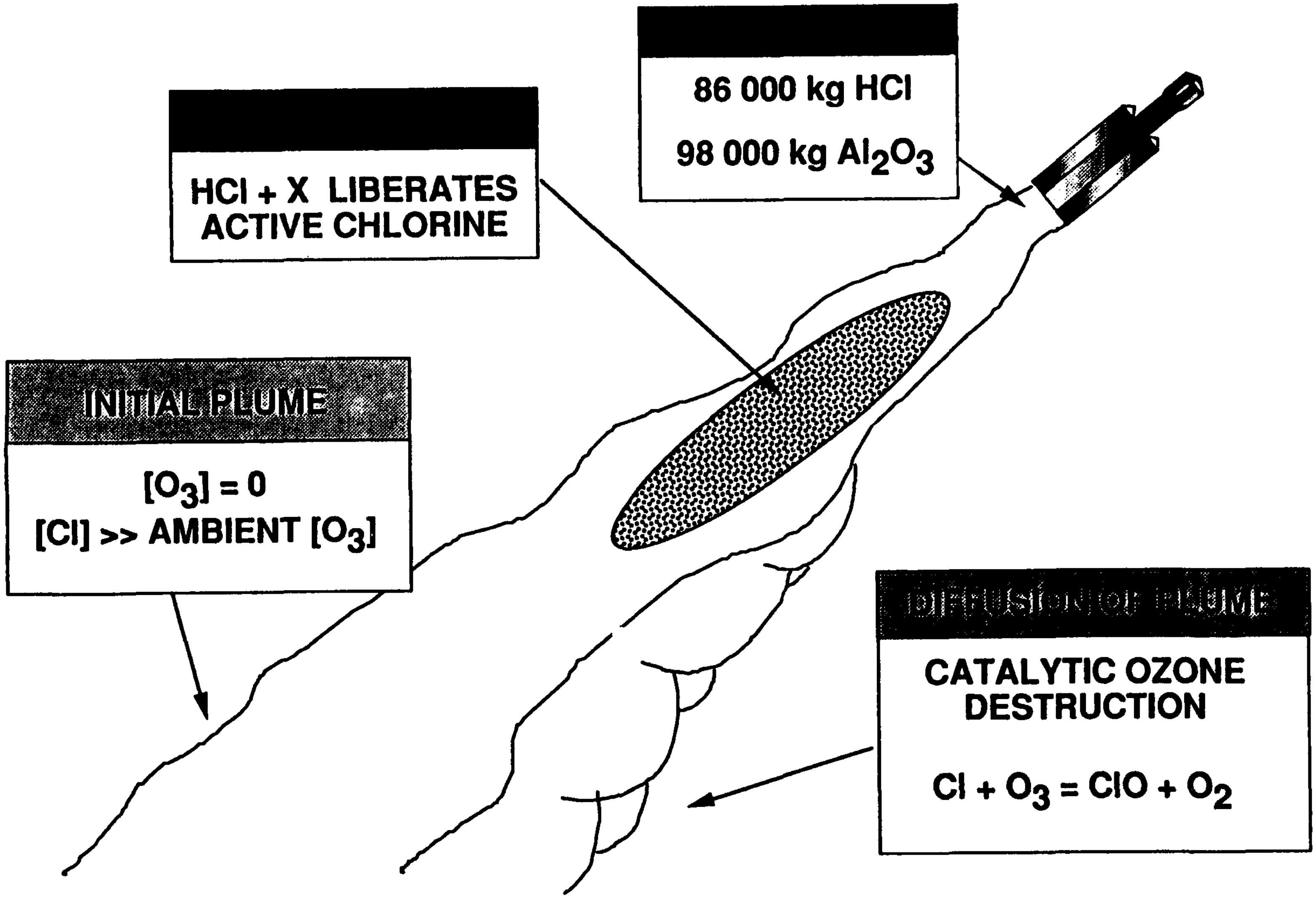
HIROIG SCIENCE

- Rockets as sources of stratospheric ozone depleting chemicals
- Characteristics of rocket plume ozone depletion
- Backscatter method of ozone measurement
- Measurement requirements for plume ozone loss detection

LAUNCH VEHICLES AS STRATOSPHERIC POLLUTERS

- motor types:
  - solids (ammonium perchlorate)
  - liquids (hypergolic, cryogenic)
- exhaust products are not well known
  - gases (CO_2, CO, OH, H_2O, NO, Cl)
  - solids (Al_2O_3 or cryogen aerosols of uncertain size distribution)
- vehicles
  - shuttle (1)
  - titan IV (.6)
  - energia (2.2)
  - ariane V (.4)

SOLID MOTOR EXHAUST CHEMISTRY



THREE STAGES IN PLUME DYNAMICS

1. initial plume: 0 to about 15 min after launch

   - optically thick
   - cools to ambient
   - from industry plume flowfield models
   - $[O_3] = 0$

2. intermediate plume: 15 min to about 6(?) hours after launch

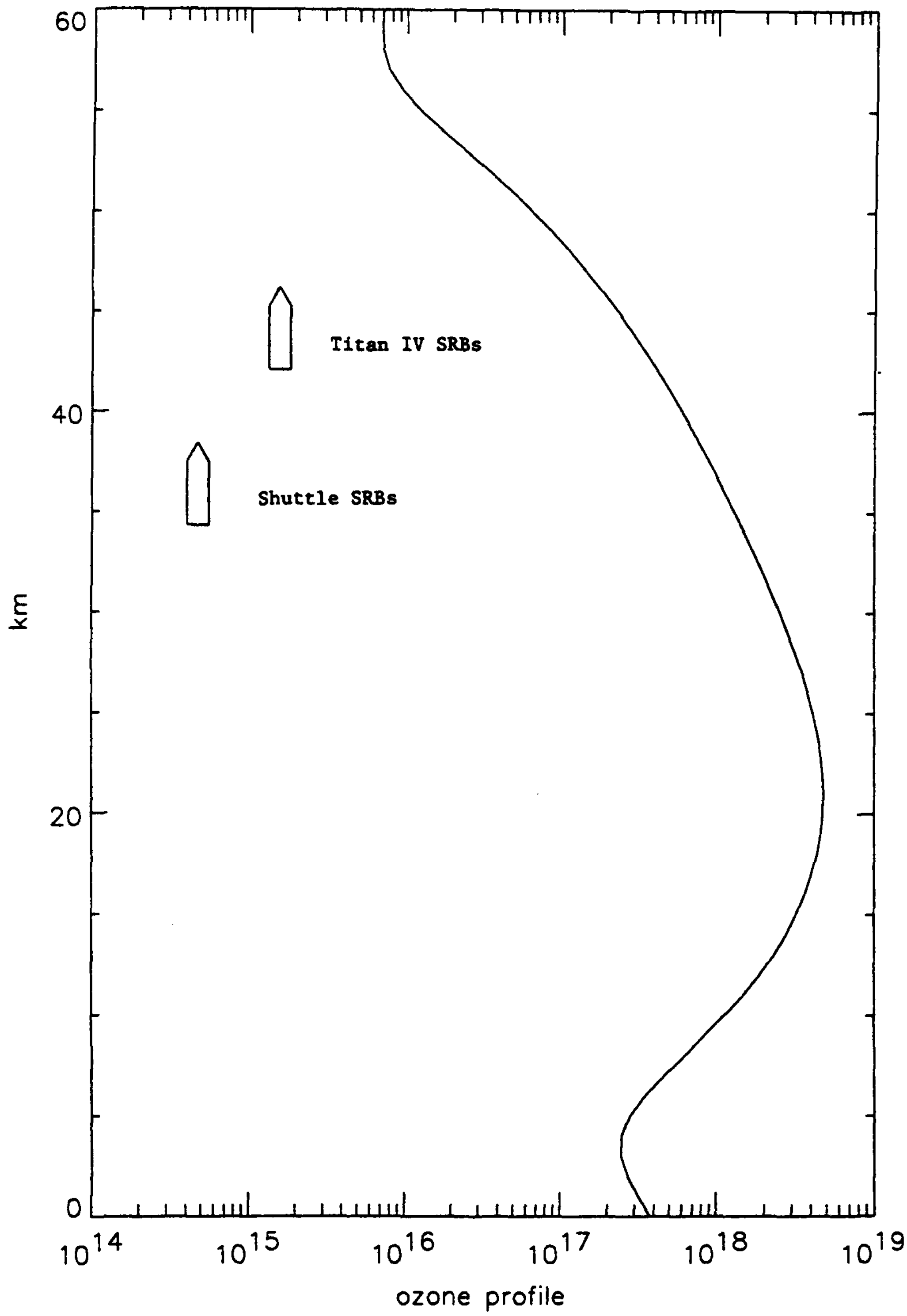
   - diffusion and advection of plume into stratosphere
   - optically thin but aerosols contribute to radiative environment
   - best chance to observe ozone loss

3. terminal plume: 6(?) hours +

   - loss of plume structure
   - diffusion of ozone rich ambient air into plume

FIRST ORDER PLUME CHEMISTRY

- Cl is very abundant in the initial plume
  - 2-5 10^{16} m^{-3}
  - $Cl + O_3$ $ClO + O_2$ is main reaction in the first hours
- as mixing proceeds in the plume O3 essentially is replaced by ClO
- detailed atmospheric chemistry models verify this view
- 3-D model needed


60
40
20
0
km
Titan IV SRBs
Shuttle SRBs
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
ozone profile

PRELIMINARY PLUME MODEL

- initial goal is for instrument design purposes

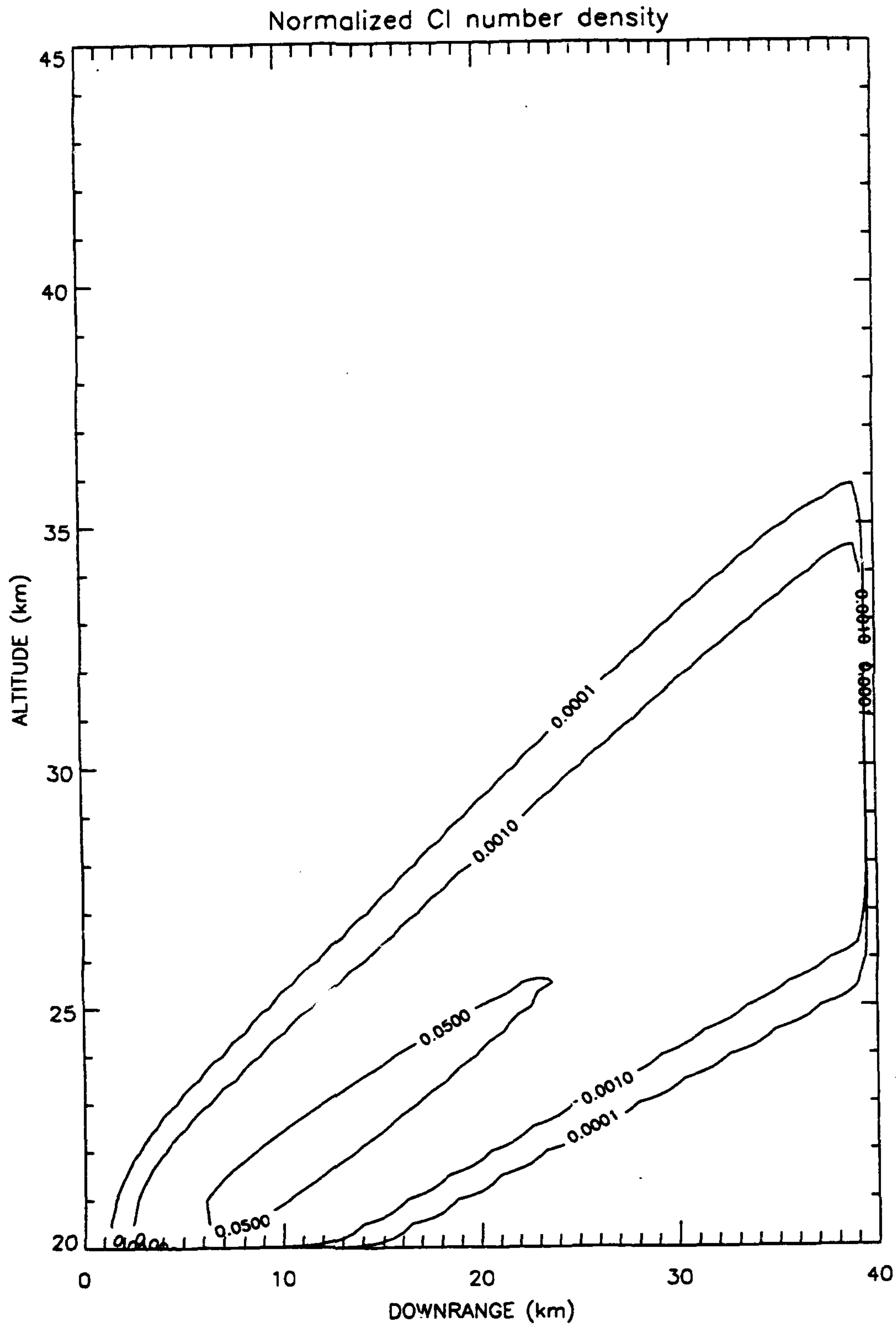
  - resolution and sensitivity
  - data rates

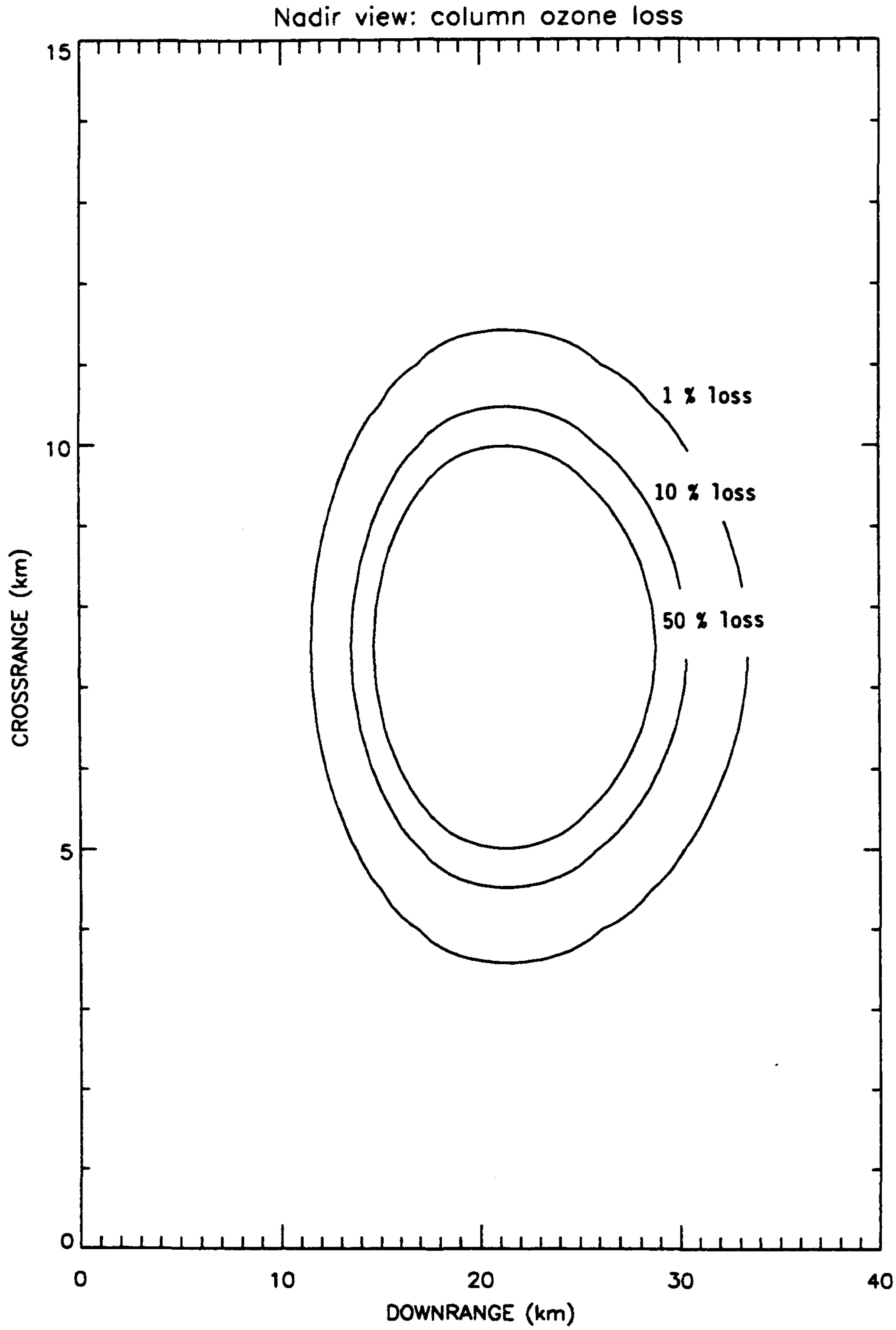
- 3-D diffusion/advection model

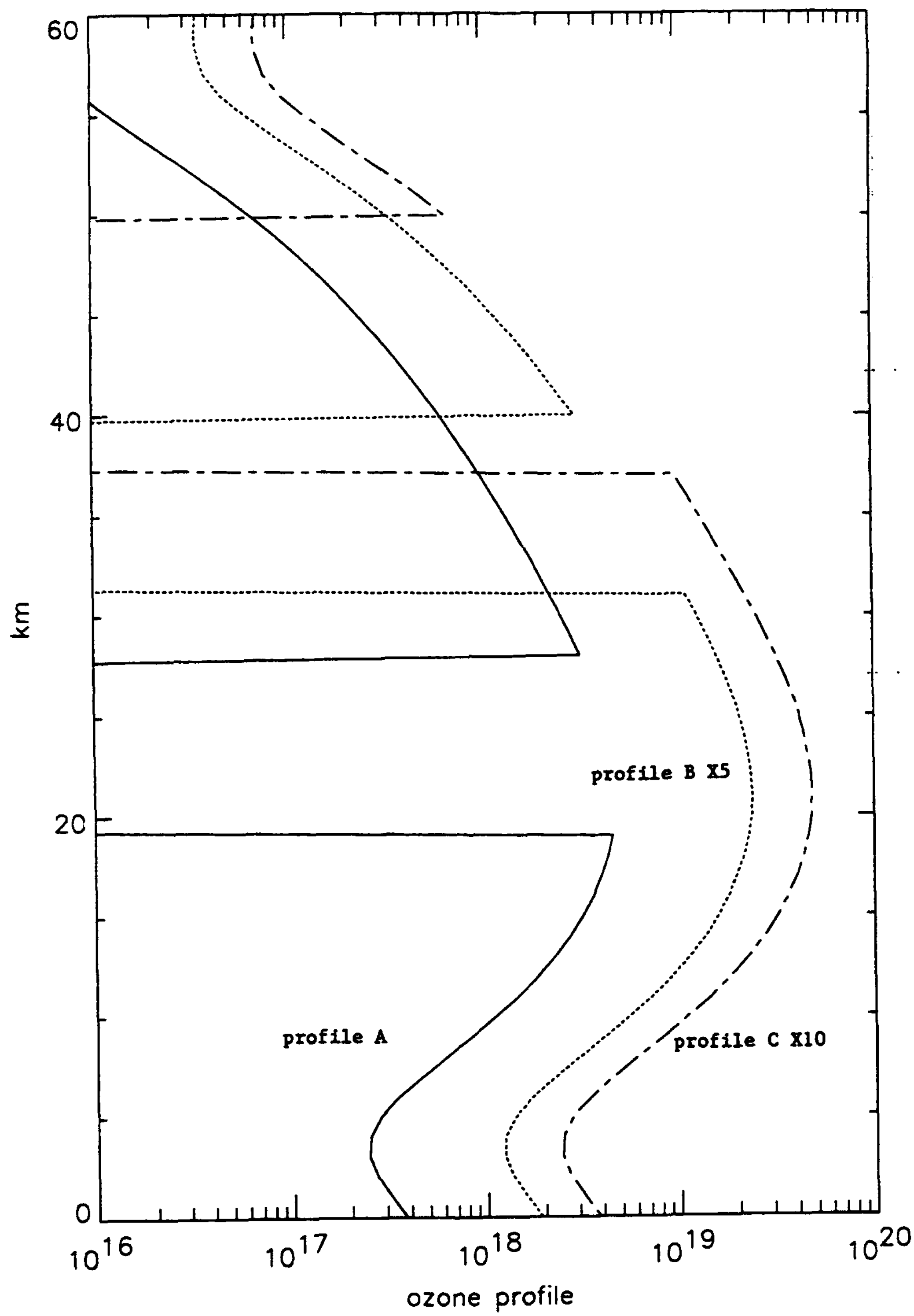
  - 'bare bones' chemistry: Cl and O_3 only
  - isothermal

- characteristics:

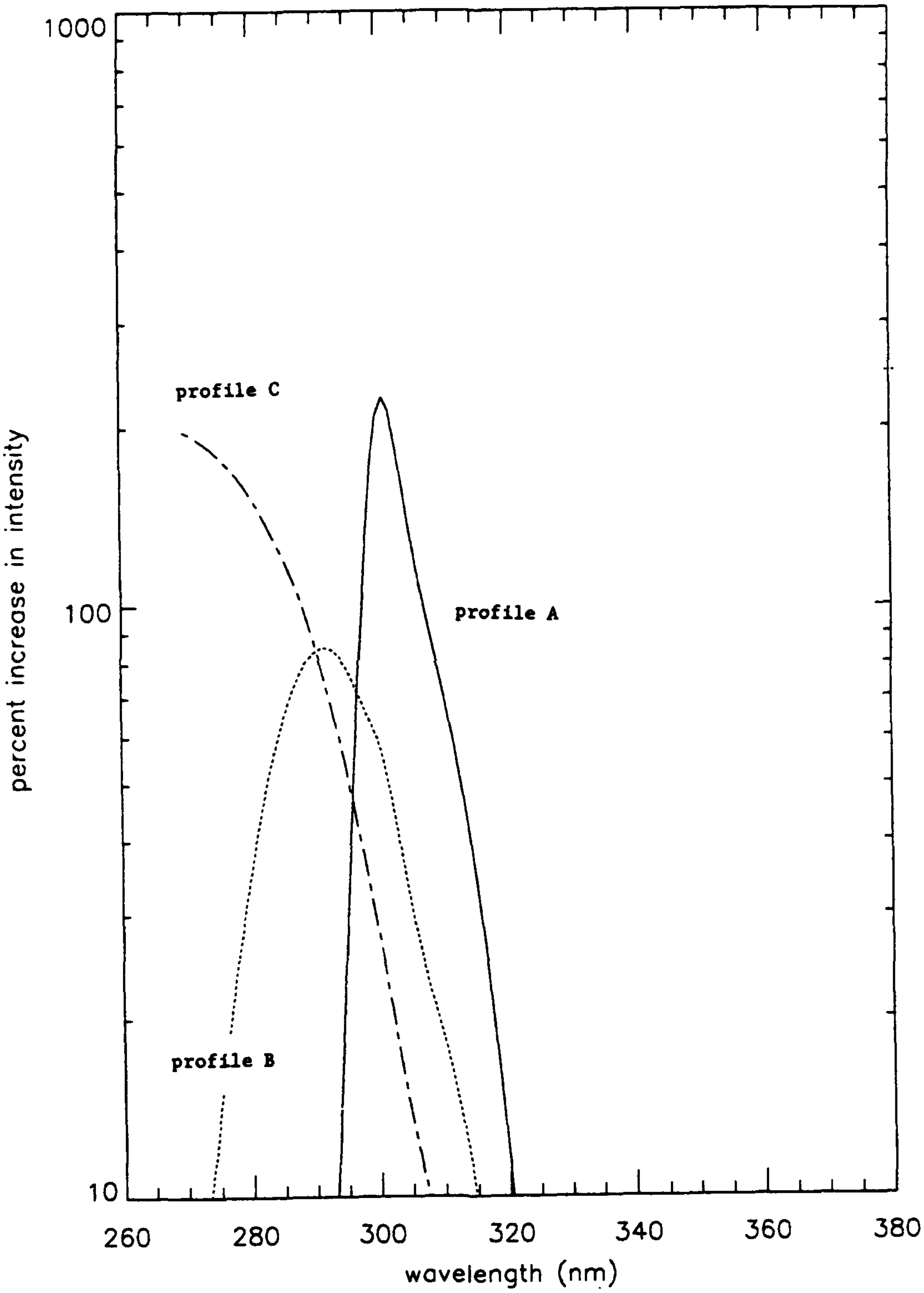
  - 20 - 45 km altitude
  - linear increase of D_h with altitude (50 - 100 m^2/s)
  - $D_h/D_v = 2$
  - trajectory parallel to wind (10 - 20 m/s)


Normalized Cl number density
ALTITUDE (km)
DOWNRANGE (km)
0.0001
0.0010
0.0500
0.0500
0.0010
0.0001
0 10 20 30 40
20 25 30 35 40 45


Nadir view: column ozone loss
1 % loss
10 % loss
50 % loss
CROSSRANGE (km)
DOWNRANGE (km)
0
5
10
15
0
10
20
30
40

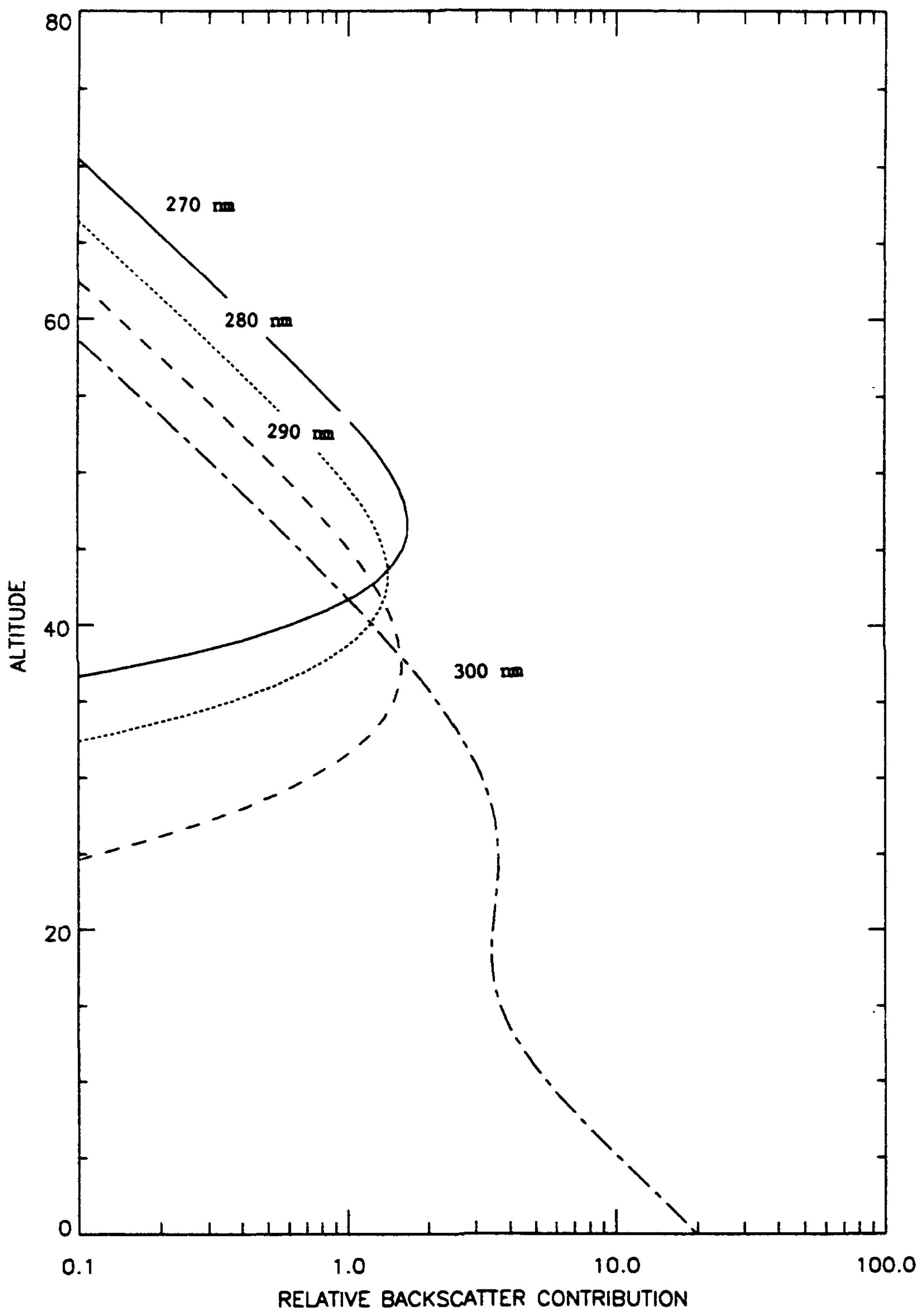


60
40
20
0
km
profile A
profile B X5
profile C X10
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
ozone profile


1000
100
10
percent increase in intensity
profile C
profile A
profile B
260
280
300
320
340
360
380
wavelength (nm)

OZONE MEASUREMENT METHOD

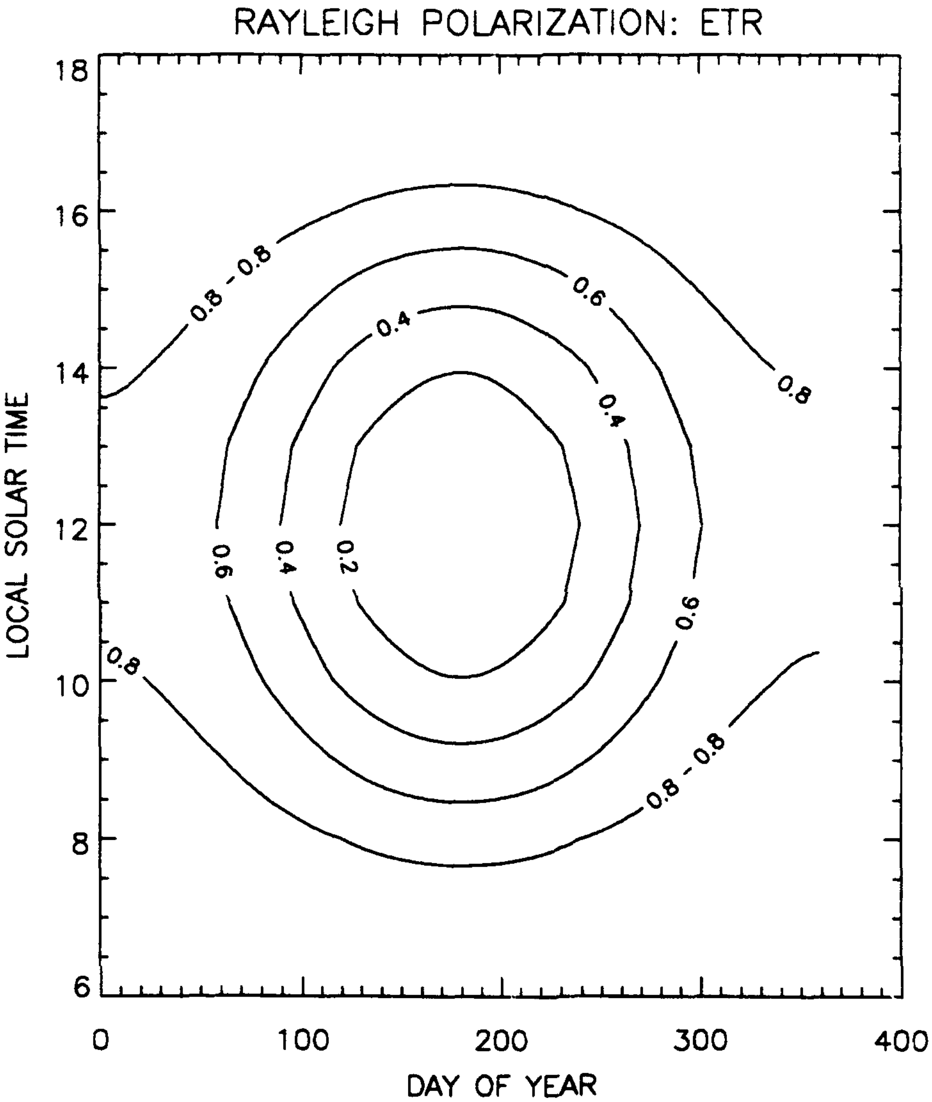
- SOLAR ULTRAVIOLET BACKSCATTER
  - EXPLOITS WAVELENGTH DEPENDENCE OF OZONE ABSORPTION
  - MID UV CONTRIBUTION FUNCTIONS COVER STRATOSPHERE FROM 20 TO 50 KM
  - VERTICAL RESOLUTION OF 5 TO 10 KM
  - LONG HERITAGE (SBUV, TOMS, DE)



80
60
40
20
0
ALTITUDE
270 nm
280 nm
290 nm
300 nm
0.1
1.0
10.0
100.0
RELATIVE BACKSCATTER CONTRIBUTION

COMPLICATIONS TO BACKSCATTER TECHNIQUE

- **Aerosols:**
  - exhuast contains .1 to 10 micron particles
  - will contribute significantly to radiative environment
  - *solution:* measure the polarization of the backscatter- molecular scattering is strongly polarized; aerosol scattering is not


RAYLEIGH POLARIZATION: ETR
LOCAL SOLAR TIME
DAY OF YEAR
6
8
10
12
14
16
18
0
100
200
300
400
0.2
0.4
0.6
0.8

COMPLICATIONS TO BACKSCATTER TECHNIQUE
(continued)

- In the plume region ozone is replaced by ClO:
  - ClO absorption cross section is similar to ozone
  - *solution:* use spectral features in ClO cross section to recover ClO profile

- Low resolution (i.e. TOMS) uses 1-D inversion: high resolution will require development of 3-D inversion

HIROIG DESIGN

- MEASUREMENT GOALS LEAD TO DESIGN SPECS

- RESOLVE PLUME	2 KM PIXELS
- OZONE PROFILE	270 -370 NM AT 2 NM
- AEROSOL COMPONENT	POLARIZATION STATE
- OBSERVE > 50% OF EVENTS	SUN SYNCHRONOUS ORBIT CROSS TRACK POINTING

INSTRUMENT REQUIREMENTS

J. H. HECHT

Feb. 17, 1993
Jim Hecht

INTRODUCTION

The High Resolution Ozone ImaGer (HIROIG) is a new space-based spectrograph:

- Ozone density
  - 800 km orbit
  - backscattered solar light 270-370 nm
- Change in Ozone after a rocket launch
  - spatial resolution (2 X 2 km)
  - NASA TOMS - 50 X 50 km pixel
- Polarization
  - aerosols

OVERVIEW

- HIROIG design - four spectrographs - CCD Detectors
  - one dimension is spectral - 270 to 370 nm
  - other dimension is spatial

- Typical CCD image
  - exposed for 1/7 second
  - 90 X 130 pixels (100 X 100 microns)
  - Focal plane of 9 X 13 mm
- 100 X 100 micron pixel
  - 1 nm spectral (270-370 nm)
  - 1 km X 1 km spatial
  - effective resolution of 2 nm and 2 X 2 km
  - 100 km by 1 km strips

- second spatial dimension via motion of the spacecraft

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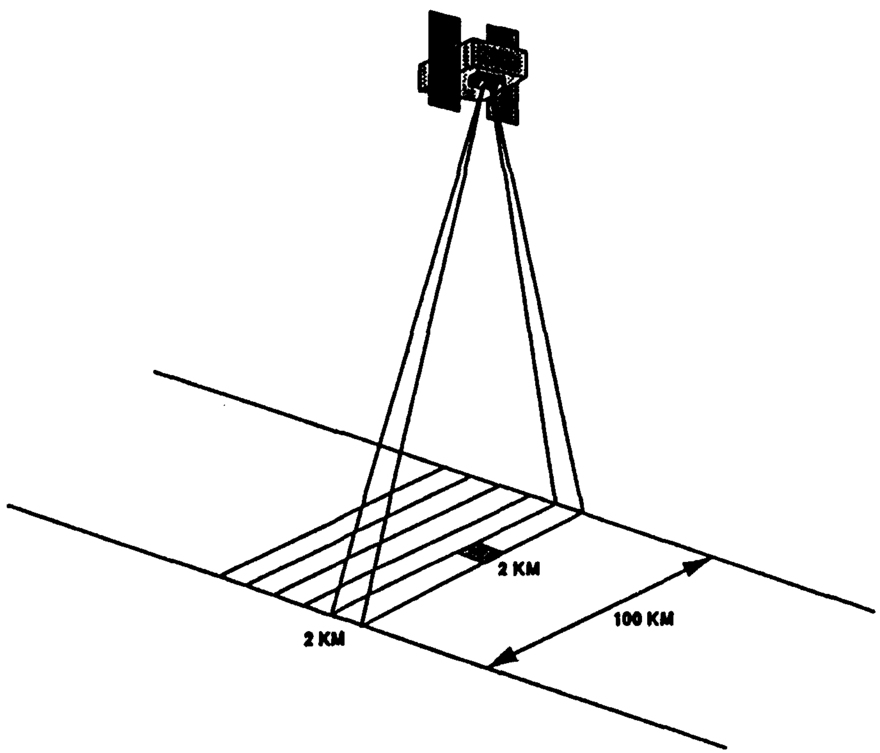
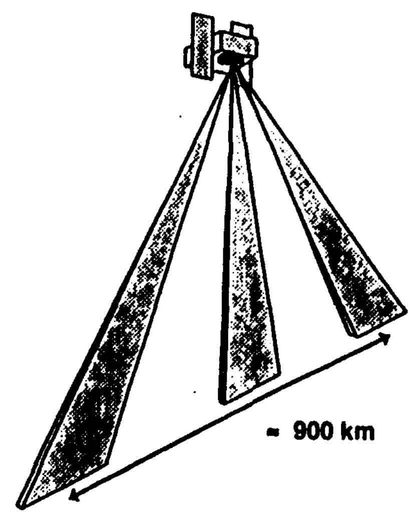
HIROIG

PUSH-BROOM OPERATION





- gimbal mounted
  - 30 degrees from nadir pointing

- The four spectrographs are each sensitive to light polarized at different angles
  - three angles - uniquely determine polarization
  - 0, 45, 90
  - fourth 0 or 135
  - increase the signal to noise in backscattered signal
  - correct for radiation induced degradation of the CCD

- HIROIG Design Difficulties
  - large amount solar light - eliminated prior to entrance slit
  - steepness of the solar curve - 270 to 370 nm (1000:1)
- Solutions
  - Pre-filtering - suppress unwanted solar photons outside the bandpass from entering the instrument
  - The optical design of the spectrograph is such that internal scattering is minimized.

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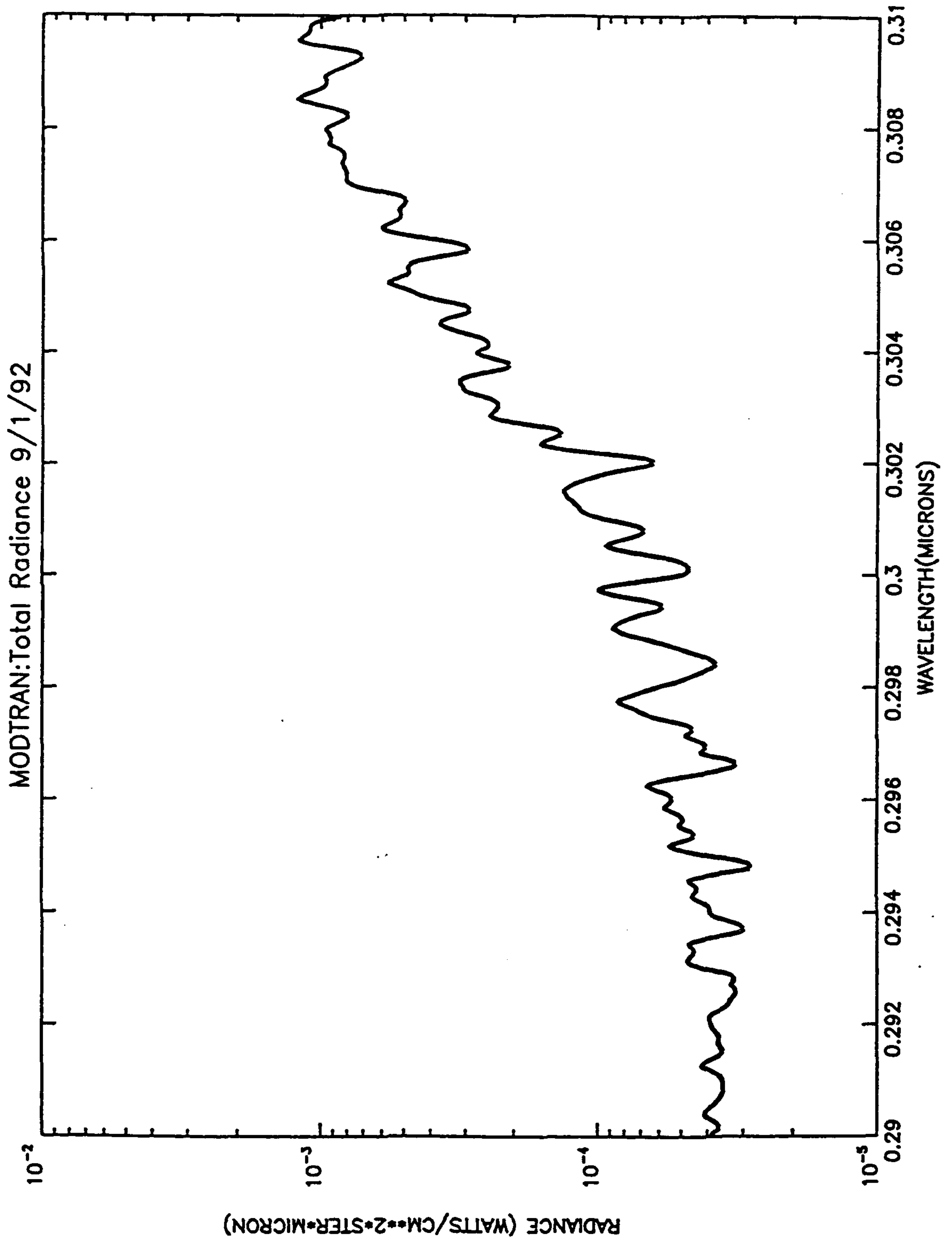
Jim Hecht

DESIGN CRITERIA

- CCD will be used as a detector
  - large signals - 10^7 counts over focal plane
  - large number of pixels - 10^4
- spectral resolution - 2 nm from 270 to 350 nm
  - goal - 1 nm through this wavelength range
- spatial resolution - 2 X 2 km at 800 km
  - goal 1 X 1 km
- cross track field of view 100 km for a slit height of 1 cm.
- Visible and Near IR solar light must be rejected
- Scattering must be low (1×10^{-6})
  - The ratio of out of band to in band light should be below 0.1%

- signal to noise for a 2 X 2 km spatial element
  - 10:1 at 270 to 290 nm
  - 30:1 throughout the rest of the spectrum
- exposure time-1/7 of a second (1 km of spacecraft motion)
- the state of polarization of the backscattered light
- pointable
- The mechanical design of the spectrograph is such that temperature fluctuations will not change the bandpass by more than 0.1 nm
- Minimize or eliminate High Voltage
- Moving parts must be kept to a minimum
  - CCD in Frame Transfer Mode


MODTRAN:Total Radiance 9/1/92
RADIANCE (WATTS/CM**2*STER*MICRON)
WAVELENGTH(MICRONS)
10⁻²
10⁻³
10⁻⁴
10⁻⁵
0.29
0.292
0.294
0.296
0.298
0.3
0.302
0.304
0.306
0.308
0.31

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FRAME TRANSFER MODE

- No mechanical shutter - CCD frame transfer mode
  - image exposed 140 msec
  - quickly transferred to a masked storage area
  - next 140 msec exposure period storage area read out
- signal level ≈ 100 counts at 270 nm to nearly 10000 counts at 305 nm.
  - Thus, to minimize either spectral smearing (if the transfer from the image to storage area is in the spectral dimension) or spatial smearing (if the transfer from the image to storage area is in the spatial dimension) the transfer should take on the order of 0.5 millisec or less.

STRAWMAN CCD REQUIREMENTS

All of the following should be stable over a three year mission lifetime with the chips deployed in a sun synchronous 800 km orbit at -30 C.

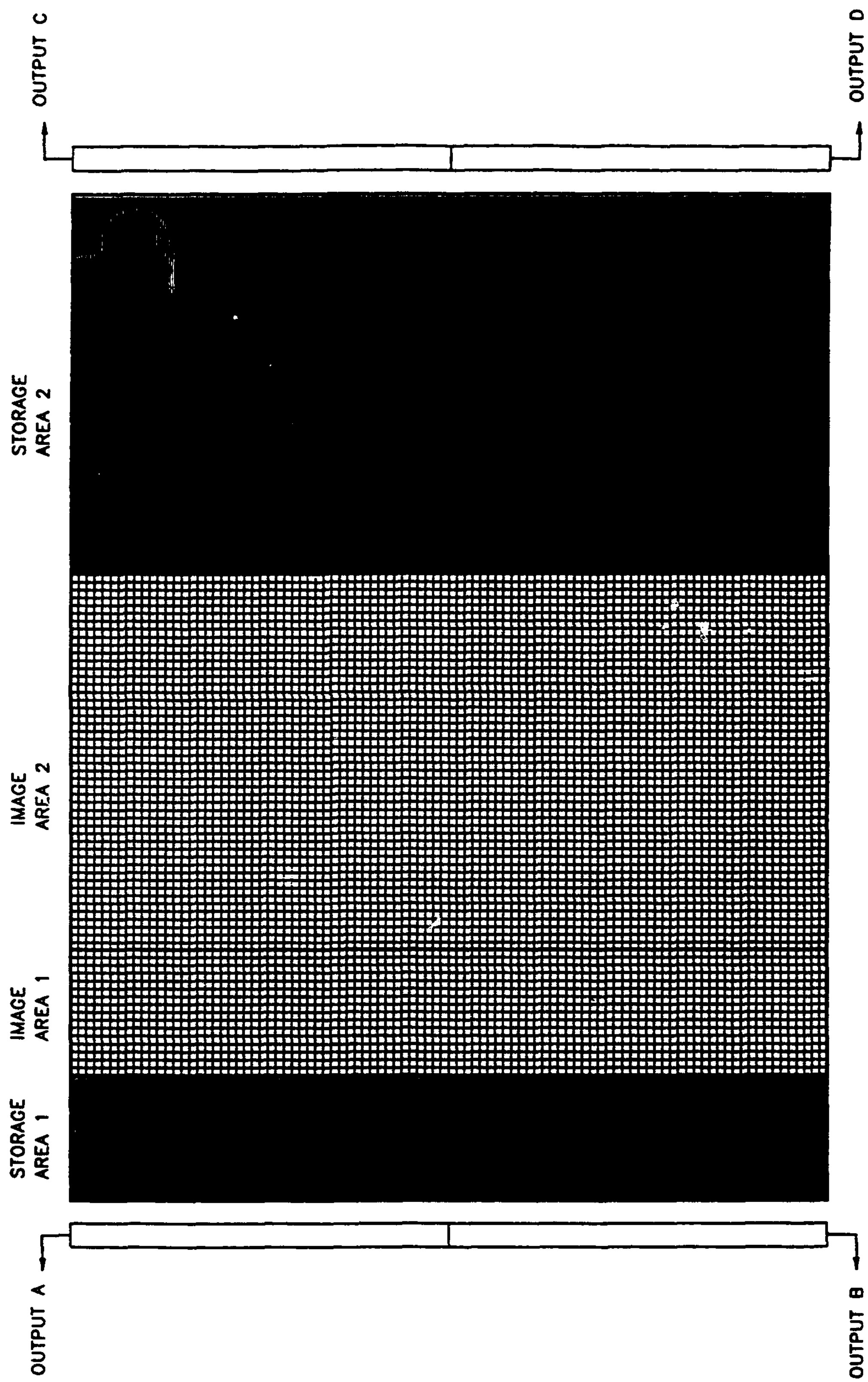
- READ NOISE-less than 10 cts RMS (goal of 5). Expected pixel read out to be about 70 kpixels/sec to 280 kpixels/sec

- DARK COUNTS - less than 50 counts/sec in a 100 micron X 100 micron pixel at -30 C (equivalent to about 1 ct/sec in a 15 X 15 micron pixel at -30 C)

- QUANTUM EFFICIENCY 15% or better from 270 to 370 nm QE must be stable

- CHARGE TRANSFER EFFICIENCY 0.99999 or better

- VERTICAL TRANSFER TIME FOR ONE LINE 2 microsec or better
- CHIP ARCHITECTURE FOR FLIGHT CCD
  - 1024 X 768 contiguous pixels with no dead space
  - pixel - 18 microns X 18 microns
  - pixel rate/amplifier - near 20 kpixels/sec to 70 kpixels/sec


OUTPUT C
OUTPUT D
STORAGE AREA 2
IMAGE AREA 2
IMAGE AREA 1
STORAGE AREA 1
OUTPUT A
OUTPUT B

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THE EFFECTS OF RADIATION ON CCDS

- Radiation doses much above 200 Rads/year at 800 km altitude will degrade the performance of the CCD.
    - The CCD must be shielded (1 cm of Tantalum)
- Even at 200 Rads/year CCD will deteriorate
    - Dark Count increases
    - Charge Transfer Efficiency (CTE) decreases

- These effects must be quantified
  - NASA Cassini-JPL tests
  - With sufficient shielding probably not a problem in first year of mission
  - May or may not effect sensitivity in 2nd and 3rd year in the 270 to 290 nm region
  - Having two identical spectrographs may mitigate this problem
- Continue to study this problem

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Jim Hecht

SUMMARY

- SPECTRAL RESOLUTION 2 nm from 270 to 350 nm
- SPATIAL RESOLUTION 2 X 2 km from 800 km orbit
- EXPOSURE TIME 1/7 sec
- SIGNAL TO NOISE
  - 10:1 at 270 nm
  - 30:1 from 290 to 370 nm
- DYNAMIC RANGE
  - Flatten Solar Spectrum
  - 12 bits (4000)
- INTERNAL SCATTERING - less than 10^{-6}
- POLARIZATION 0,45, and 90 degrees

- FIELD OF VIEW 100 km Cross Track
  - Pointable - 30 degrees of nadir
- MECHANICAL AND THERMAL STABILITY
  - Center of bandpass must be known to 0.1 nm
- CCD DETECTOR
  - Cooled to -30 C
  - Read Noise below 10 counts RMS
  - QE 15% from 270 to 370 nm
  - CTE 0.99999 or better for first year of operation
  - Shielded - 200 Rads /year
  - Data Rate 15 to 300 kpixels/sec (15 Mbits/sec)
  - Data Storage 2 Gbits - 1000 km

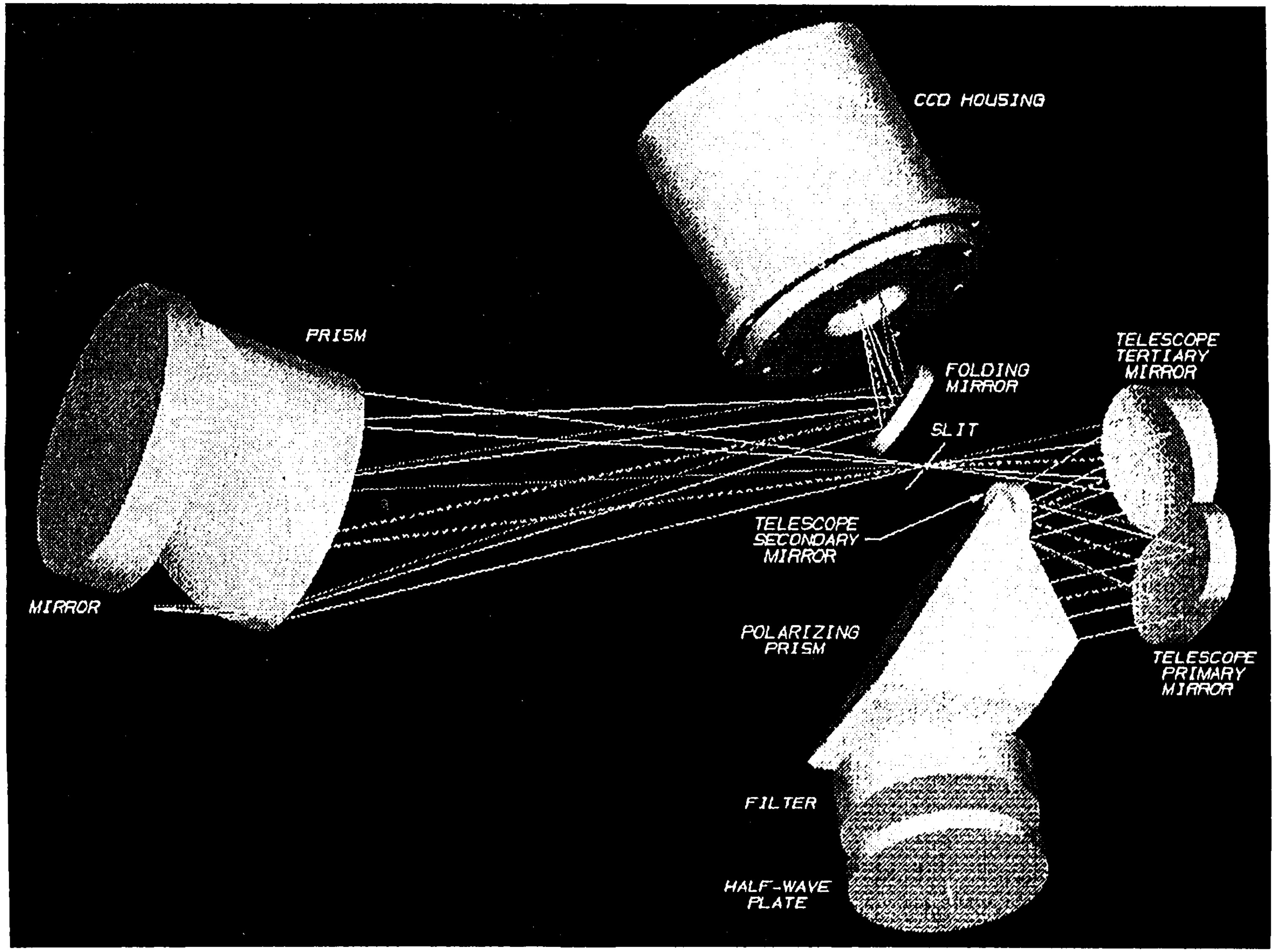
OPTICAL DESIGN

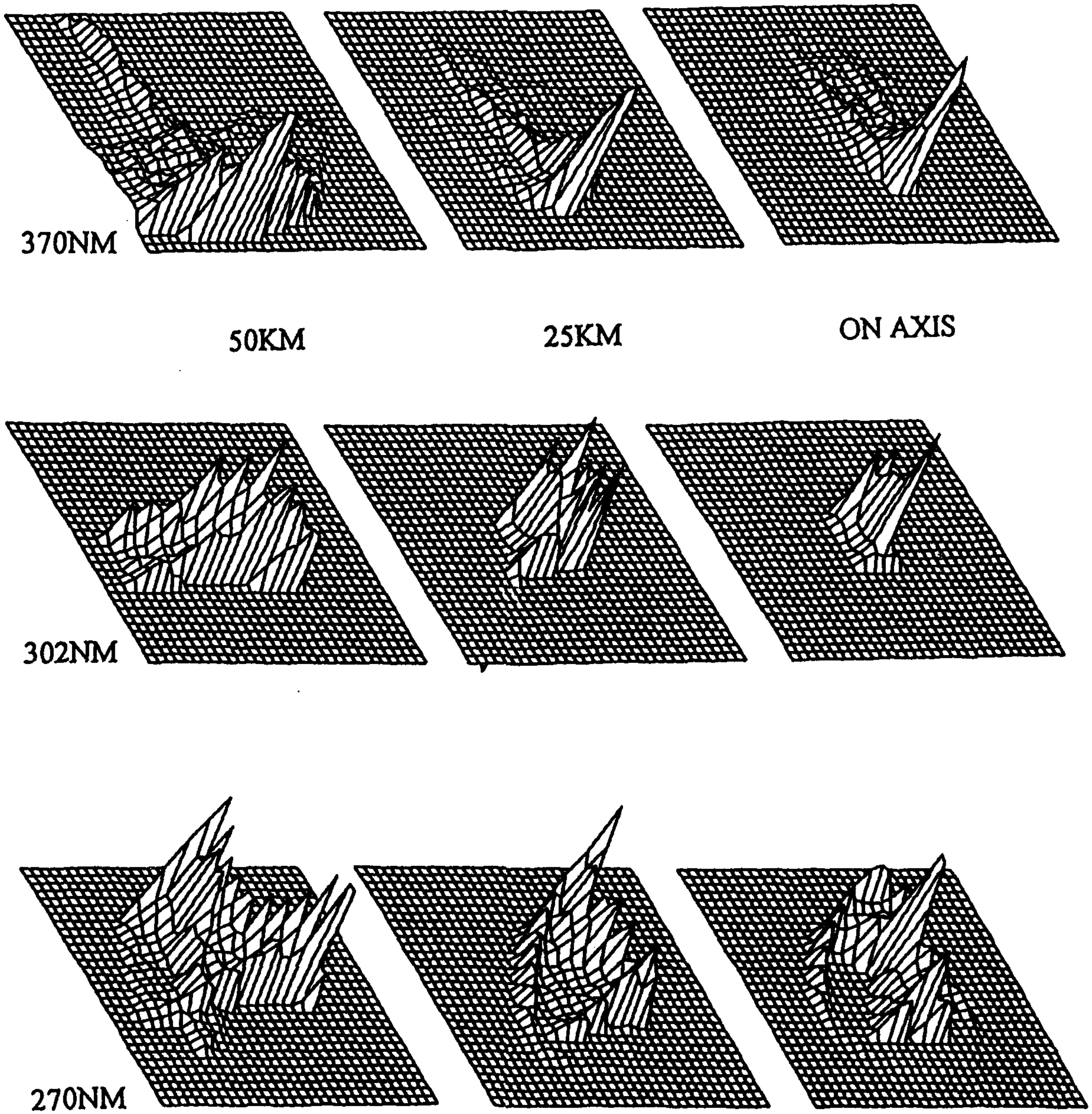
D. J. GUTIERREZ

OPTICAL DESIGN

- OPTICAL LAYOUT -- PRISM DISCUSSION
- IMAGING PERFORMANCE
- RESPONSIVITY
- SIGNAL RATES

OPTICAL LAYOUT

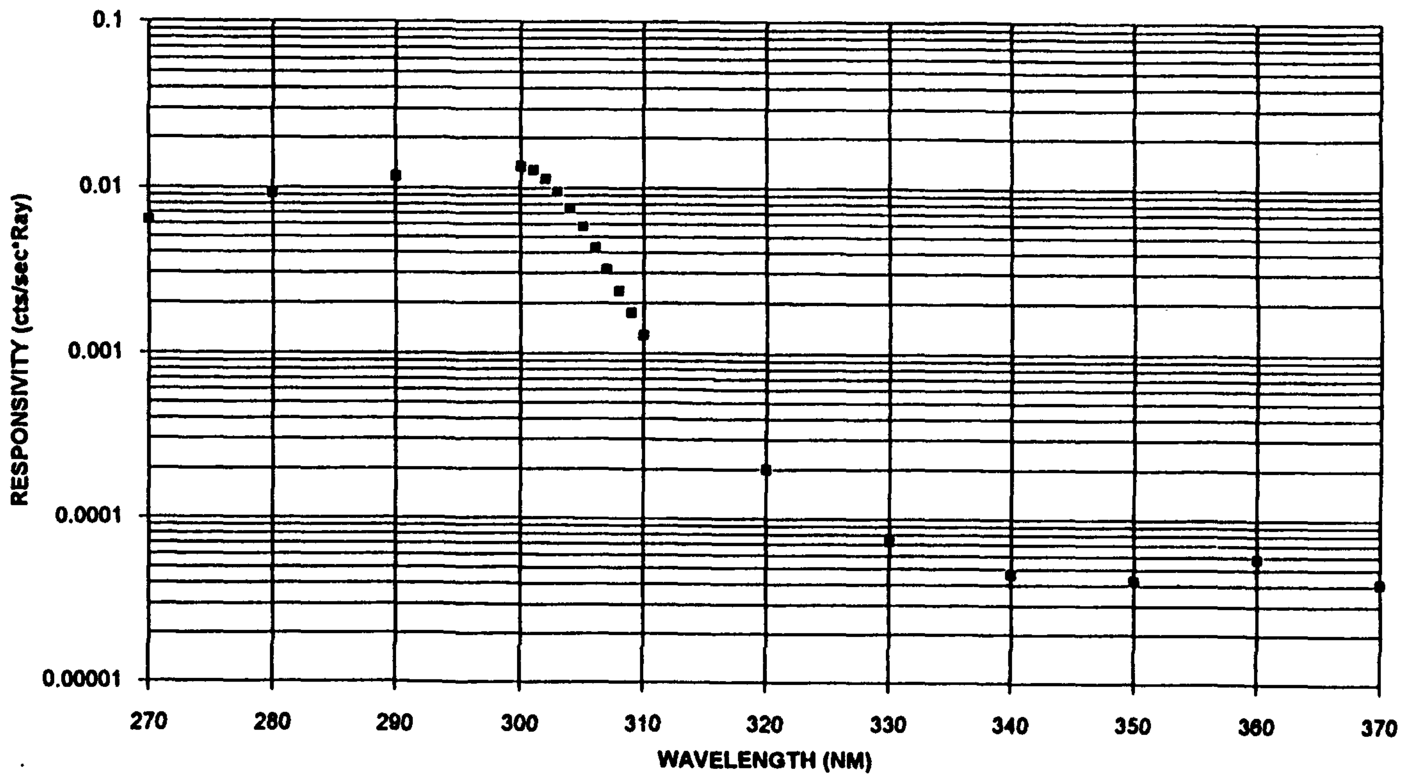




IMAGING PERFORMANCE

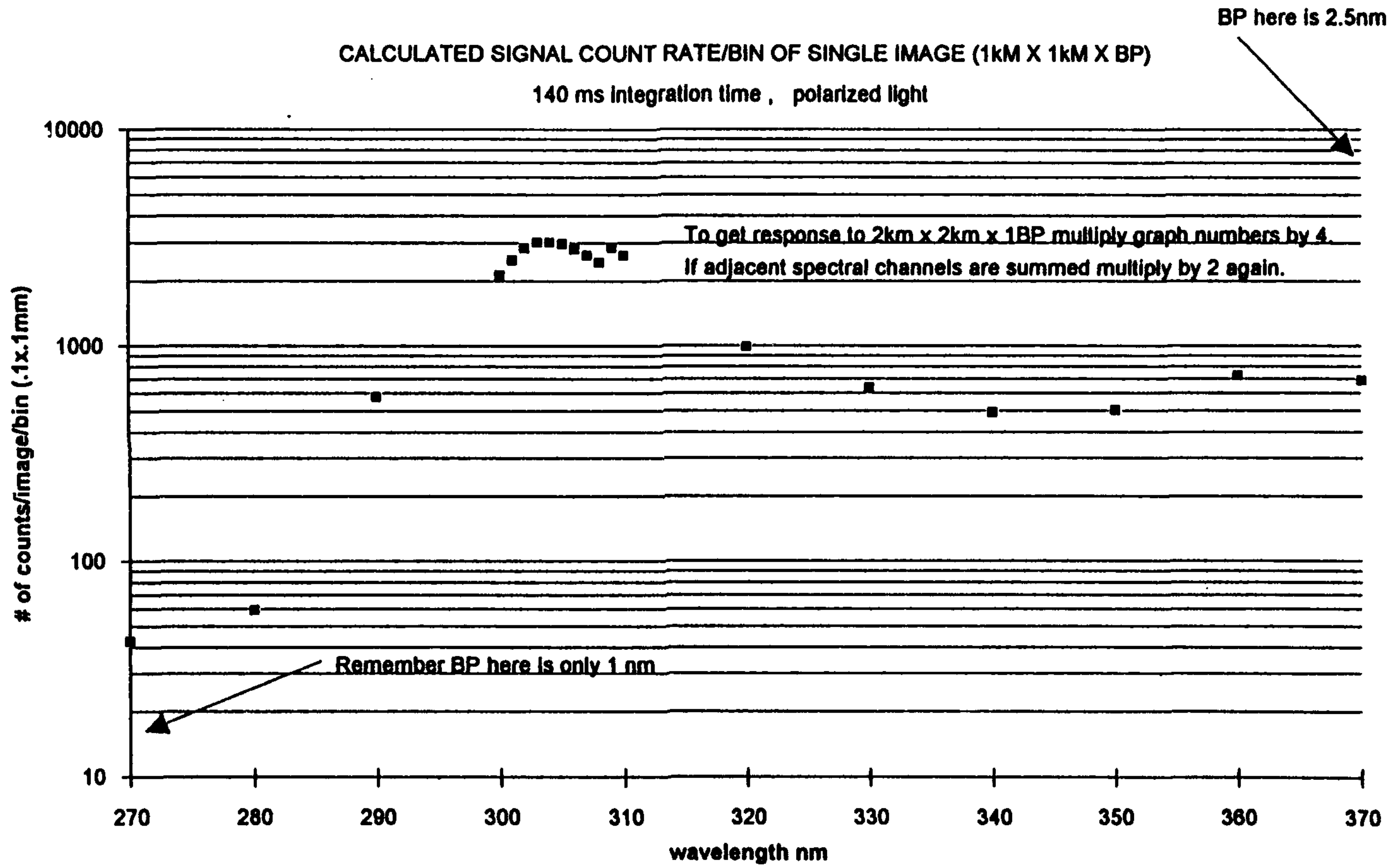
RESPONSE.XLS Chart 2

CALCULATED RESPONSIVITY OF HIROIG



RESPONSIVITY

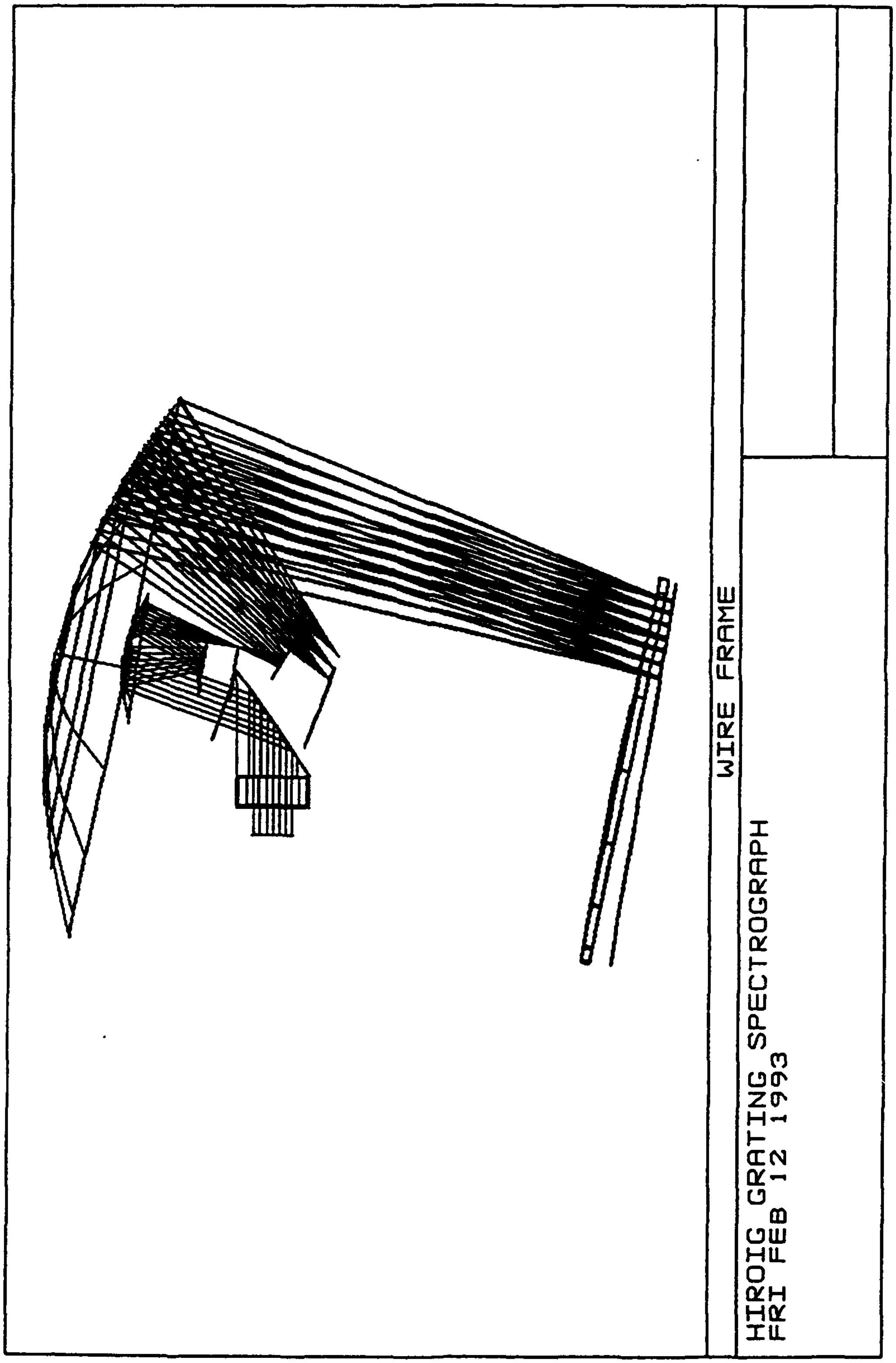
RESPONSE.XLS Chart 3

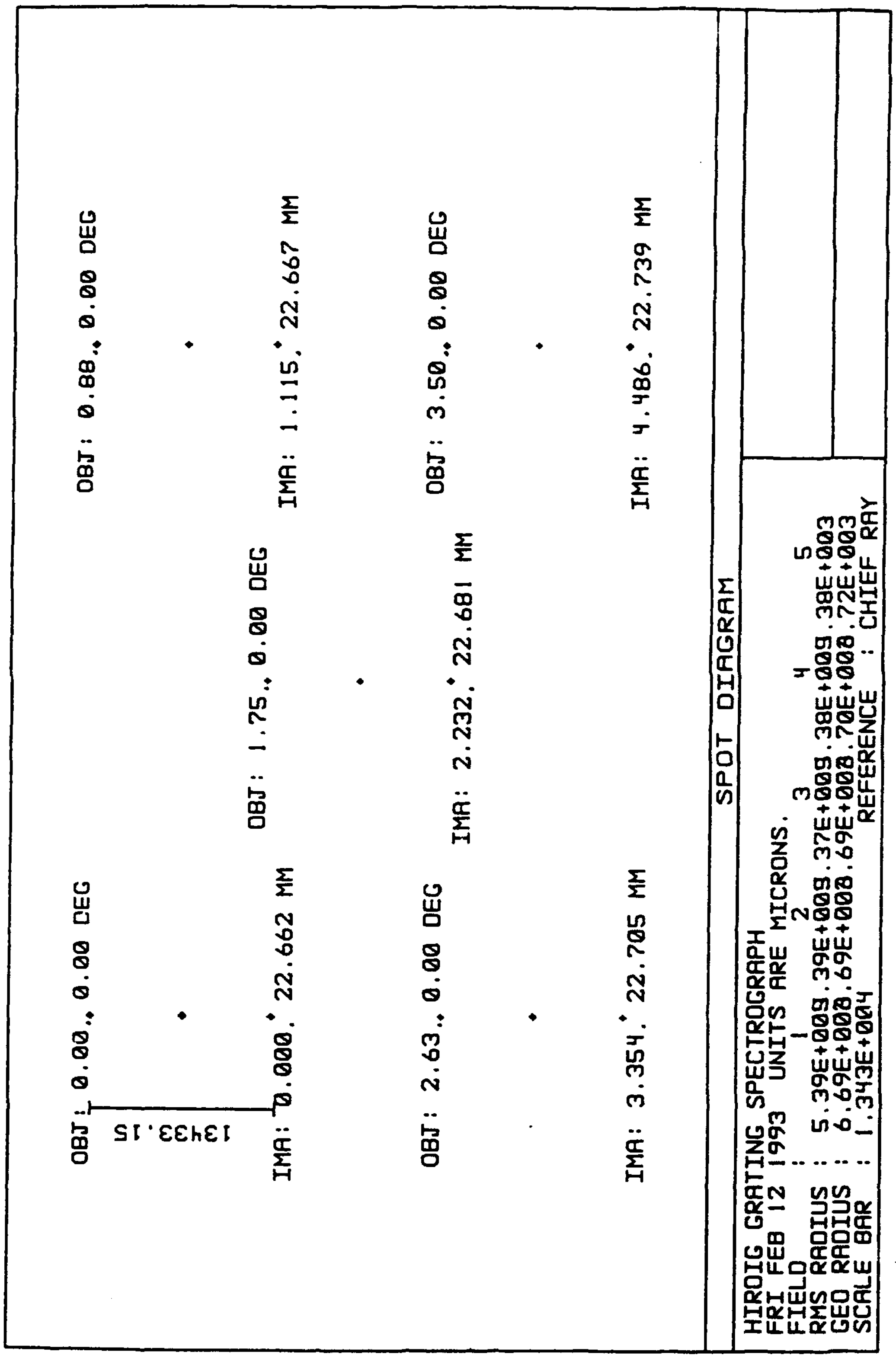


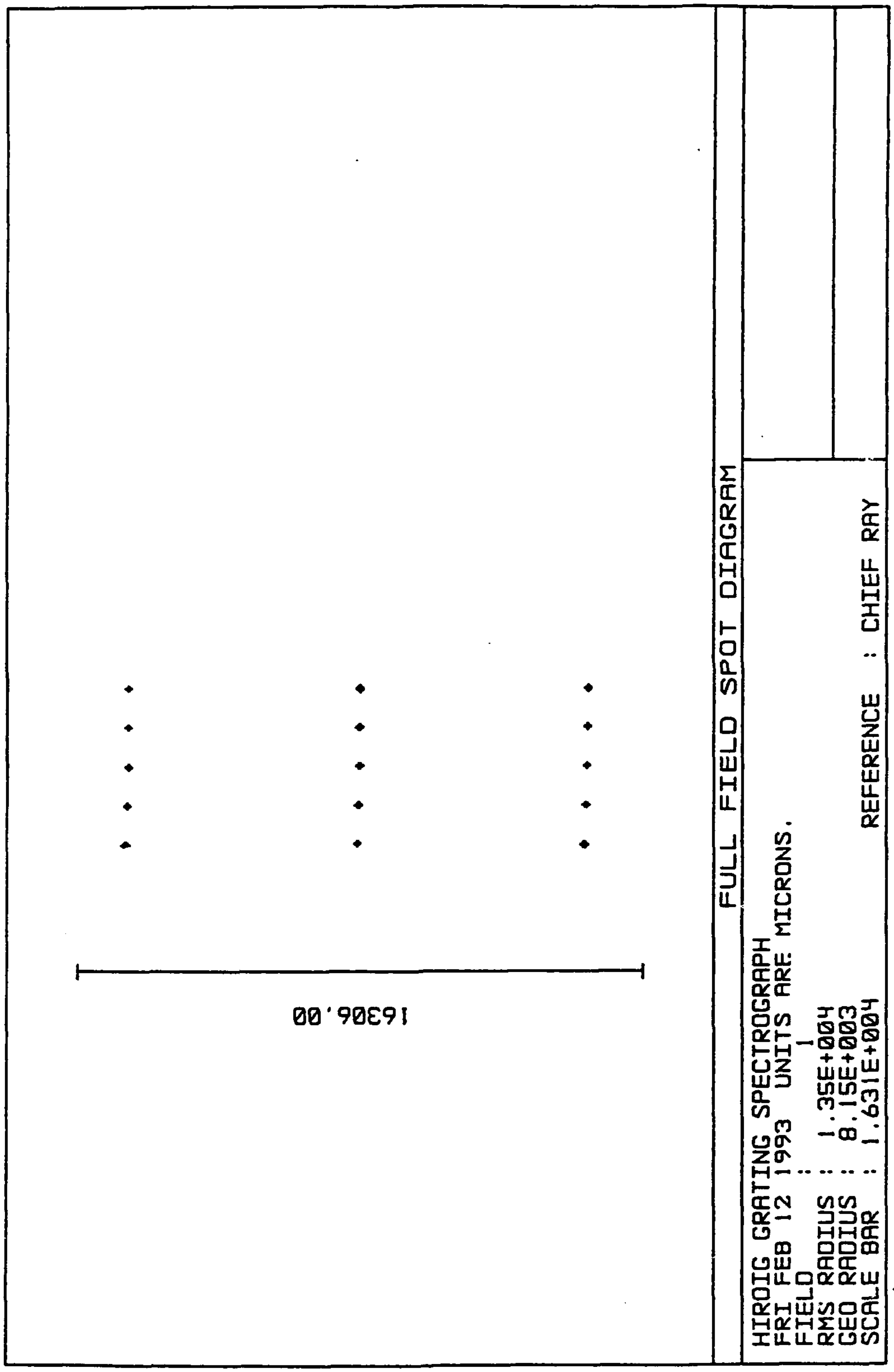
SIGNAL RATES

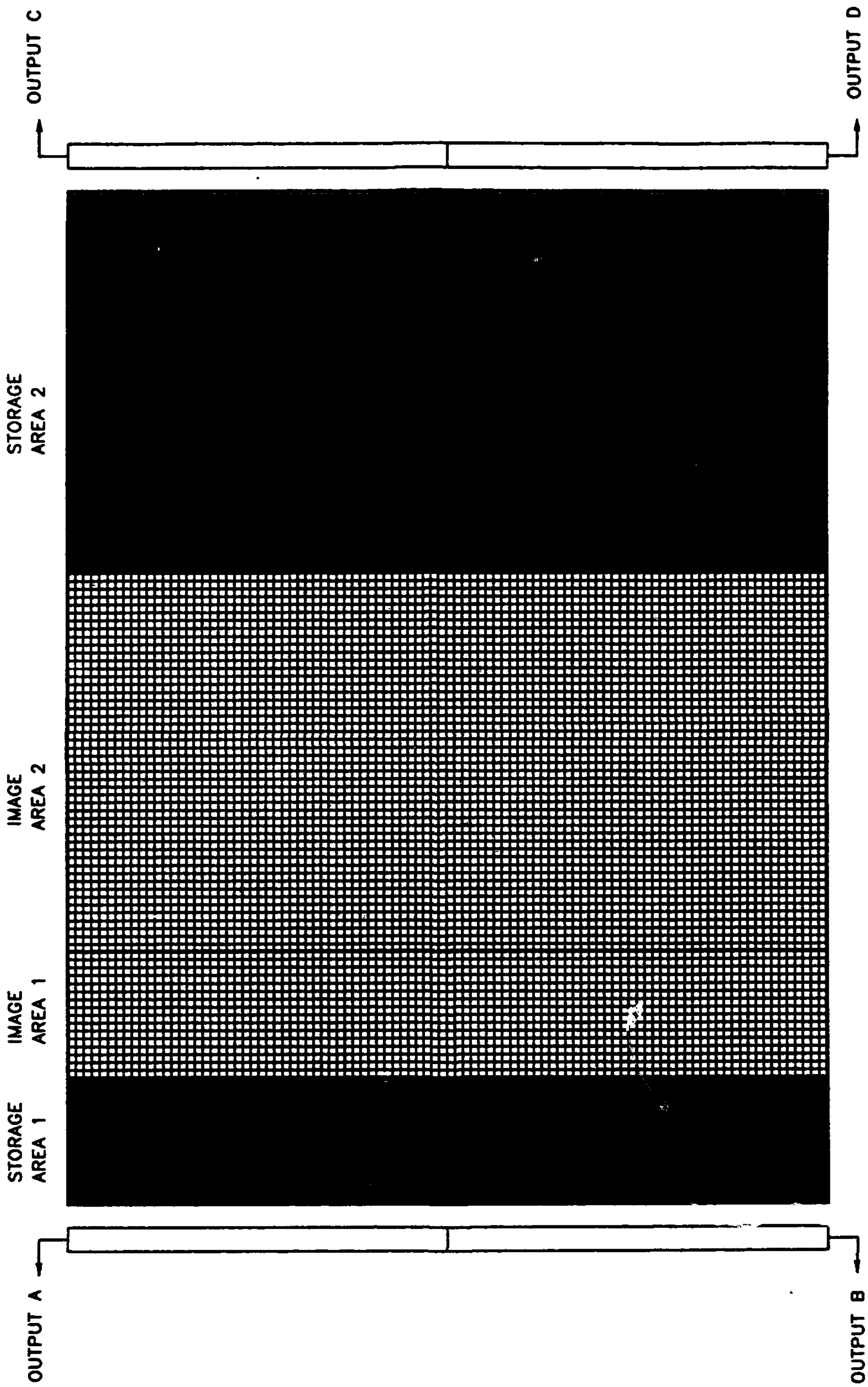
OPTICAL DESIGN

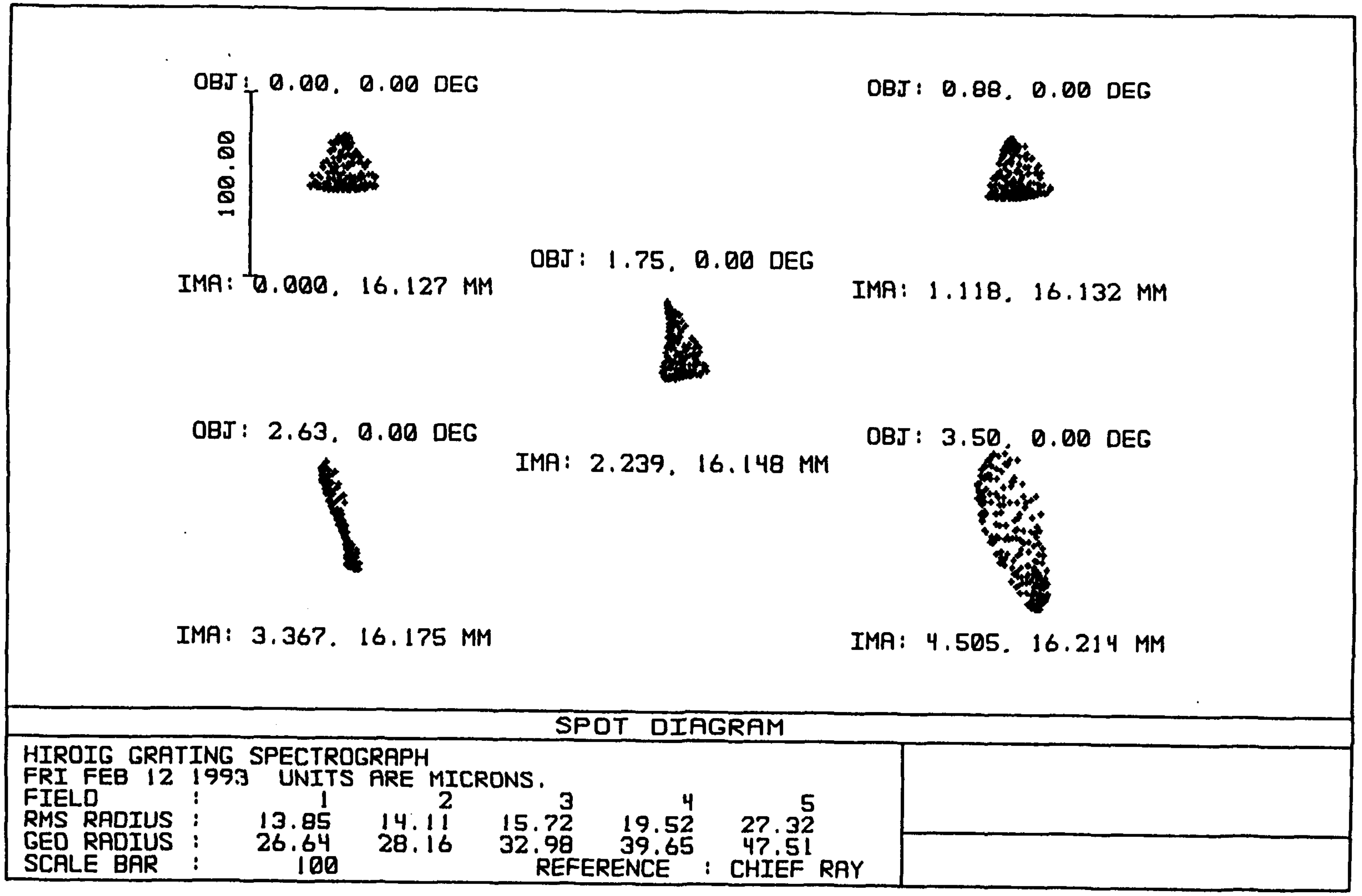
G. S. ROSSANO

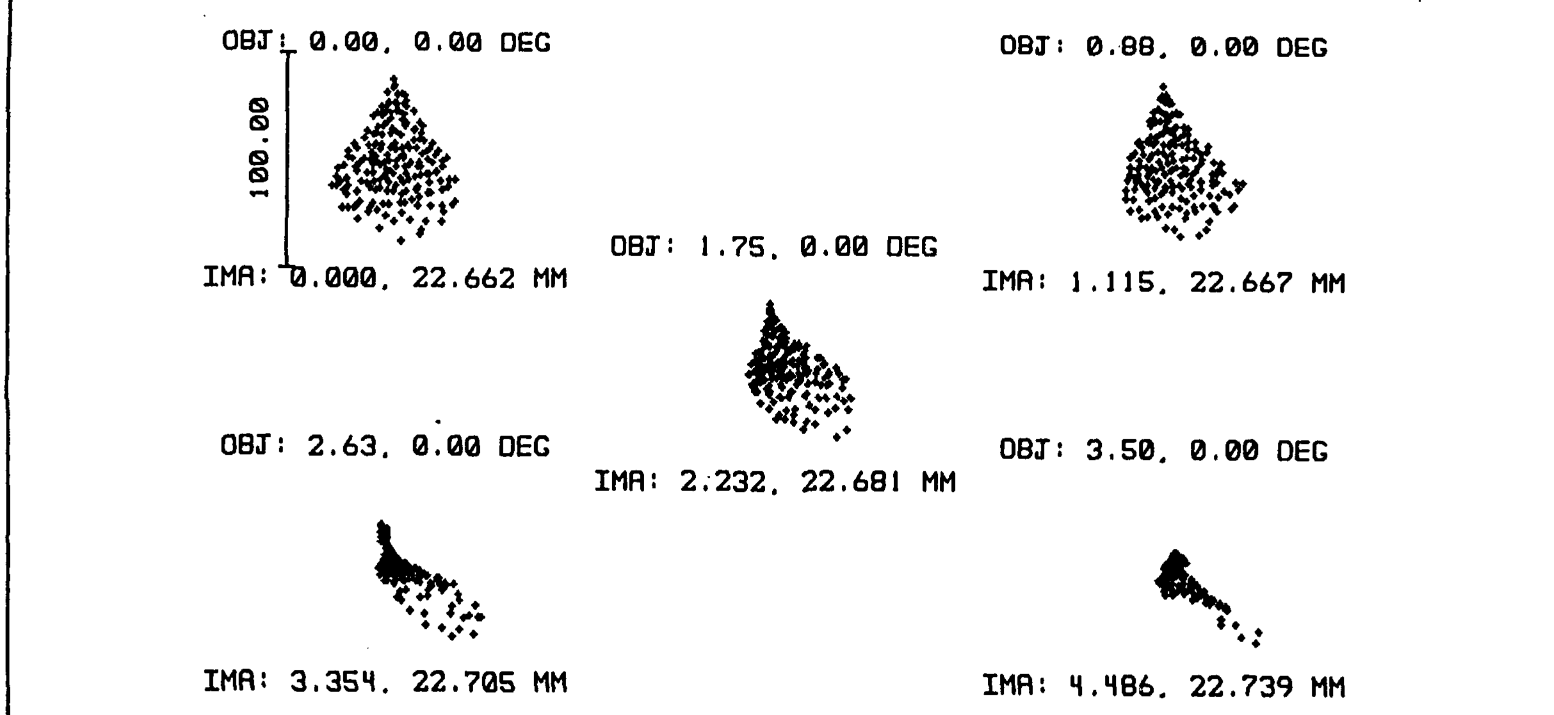

WIRE FRAME
HIROIG GRATING SPECTROGRAPH
FRI FEB 12 1993


OBJ: 0.00, 0.00 DEG
IMA: 0.000, 22.662 MM
13433.15
OBJ: 1.75, 0.00 DEG
IMA: 2.232, 22.681 MM
OBJ: 0.88, 0.00 DEG
IMA: 1.115, 22.667 MM
OBJ: 2.63, 0.00 DEG
IMA: 3.354, 22.705 MM
OBJ: 3.50, 0.00 DEG
IMA: 4.486, 22.739 MM
SPOT DIAGRAM
HIRDIG GRATING SPECTROGRAPH
FRI FEB 12 1993 UNITS ARE MICRONS.
FIELD : 1 2 3 4 5
RMS RADIUS : 5.39E+009.39E+009.37E+009.38E+009.38E+003
GEO RADIUS : 6.69E+008.69E+008.69E+008.70E+008.72E+003
SCALE BAR : 1.343E+004 REFERENCE : CHIEF RAY


16306.00
FULL FIELD SPOT DIAGRAM
HIROIG GRATING SPECTROGRAPH
FRI FEB 12 1993 UNITS ARE MICRONS.
FIELD : 1
RMS RADIUS : 1.35E+004
GEO RADIUS : 8.15E+003
SCALE BAR : 1.631E+004
REFERENCE : CHIEF RAY


OUTPUT C
OUTPUT D
STORAGE AREA 2
IMAGE AREA 2
IMAGE AREA 1
STORAGE AREA 1
OUTPUT A
OUTPUT B

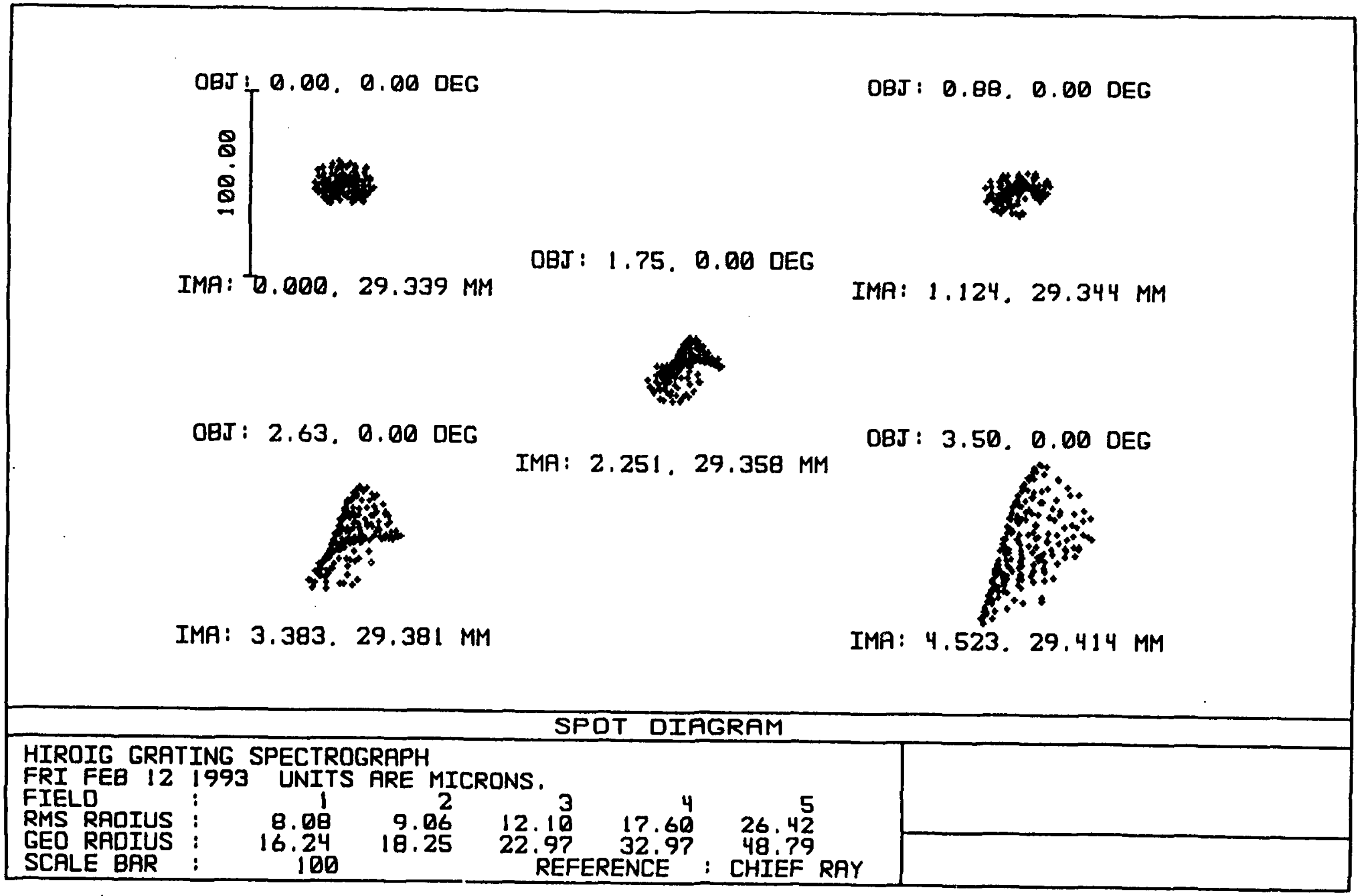

OBJ: 0.00, 0.00 DEG
100.00
IMA: 0.000, 16.127 MM
OBJ: 0.88, 0.00 DEG
IMA: 1.118, 16.132 MM
OBJ: 1.75, 0.00 DEG
IMA: 2.239, 16.148 MM
OBJ: 2.63, 0.00 DEG
IMA: 3.367, 16.175 MM
OBJ: 3.50, 0.00 DEG
IMA: 4.505, 16.214 MM
SPOT DIAGRAM
HIROIG GRATING SPECTROGRAPH
FRI FEB 12 1993 UNITS ARE MICRONS.
FIELD : 1 2 3 4 5
RMS RADIUS : 13.85 14.11 15.72 19.52 27.32
GEO RADIUS : 26.64 28.16 32.98 39.65 47.51
SCALE BAR : 100 REFERENCE : CHIEF RAY



SPOT DIAGRAM

HIROIG GRATING SPECTROGRAPH
FRI FEB 12 1993 UNITS ARE MICRONS.

FIELD :	1	2	3	4	5
RMS RADIUS :	20.76	19.73	17.45	14.97	12.62
GEO RADIUS :	38.04	36.05	43.32	49.59	52.91
SCALE BAR :	100		REFERENCE : CHIEF RAY		

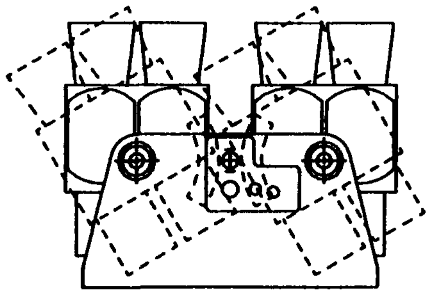

OBJ: 0.00, 0.00 DEG
100.00
IMA: 0.000, 29.339 MM
OBJ: 0.88, 0.00 DEG
IMA: 1.124, 29.344 MM
OBJ: 1.75, 0.00 DEG
IMA: 2.251, 29.358 MM
OBJ: 2.63, 0.00 DEG
IMA: 3.383, 29.381 MM
OBJ: 3.50, 0.00 DEG
IMA: 4.523, 29.414 MM
SPOT DIAGRAM
HIROIG GRATING SPECTROGRAPH
FRI FEB 12 1993 UNITS ARE MICRONS.
FIELD : 1 2 3 4 5
RMS RADIUS : 8.08 9.06 12.10 17.60 26.42
GEO RADIUS : 16.24 18.25 22.97 32.97 48.79
SCALE BAR : 100 REFERENCE : CHIEF RAY

MECHANICAL DESIGN

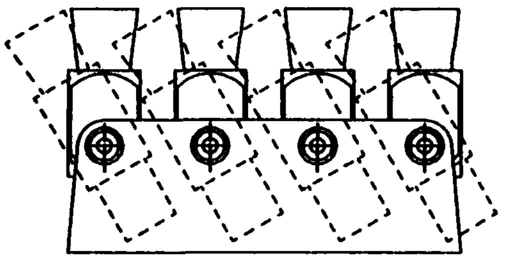
M. G. SIVJEE

HIROIG MECHANICAL CONSIDERATIONS

- FOUR SPECTROGRAPHS CO-ALIGNED TO WITHIN $\pm.007°$ (25 ARC-SEC)
- SWEEP MOTION CAPABILITY OF $\pm 30°$
- PRECISION MOUNTING AND ALIGNMENT OF OPTICS
- COOLING OF CCD's
- RADIATION SHIELDING OF CCD's



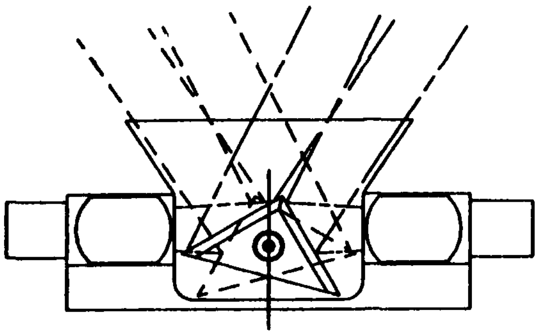
TWO LINKED PAIRS



FOUR MECHANICALLY LINKED INSTRUMENTS

DIFFICULT TO MAINTAIN CO-ALIGNMENT

BASE MUST BE RIGID AND MOUNTED TO THE SPACECRAFT AT ONLY 3 POINTS SO THAT SPACECRAFT THERMAL INSTABILITY DOES NOT CHANGE INSTRUMENT CO-ALIGNMENT

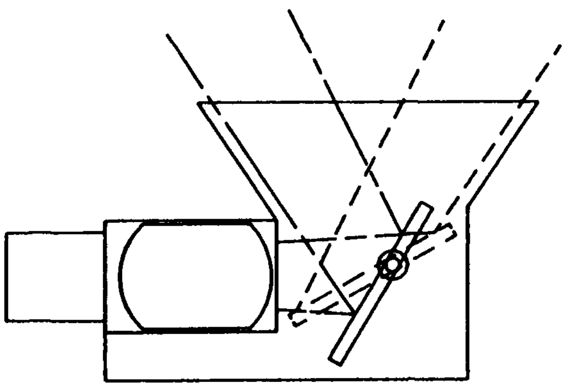


FOUR POINTING MIRRORS

INSTRUMENTS FIXED TO BASE

FOUR SLIGHTLY DIFFERENT CCD IMAGES
BECAUSE OPTICAL ELEMENTS ARE REVERSED

RELATIVELY EASY TO CO-ALIGN

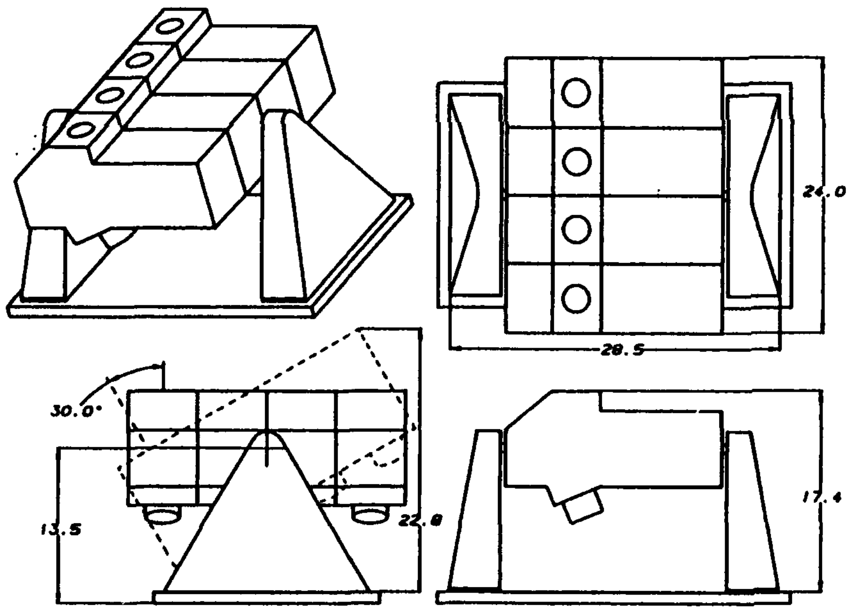


ONE LARGER INSTRUMENT

SINGLE POINTING MIRROR

ROTATING POLARIZER

REQUIRES CCD AND ELECTRONICS
TO OPERATE MANY TIMES FASTER

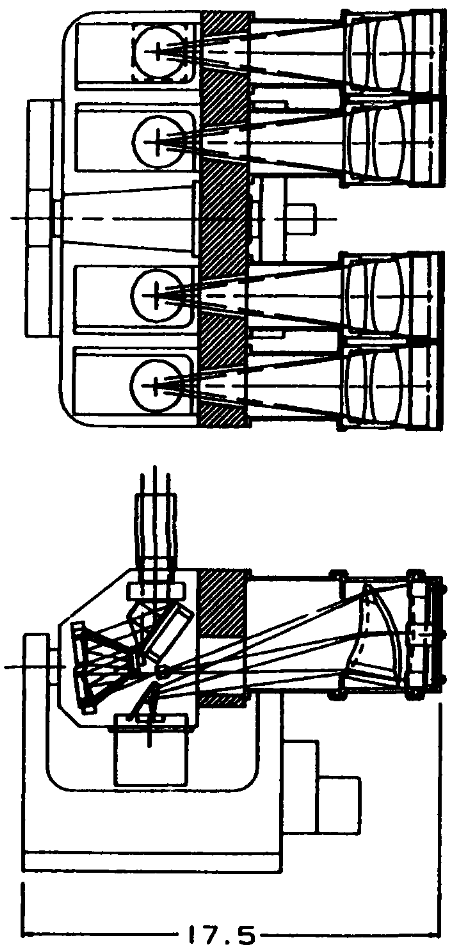


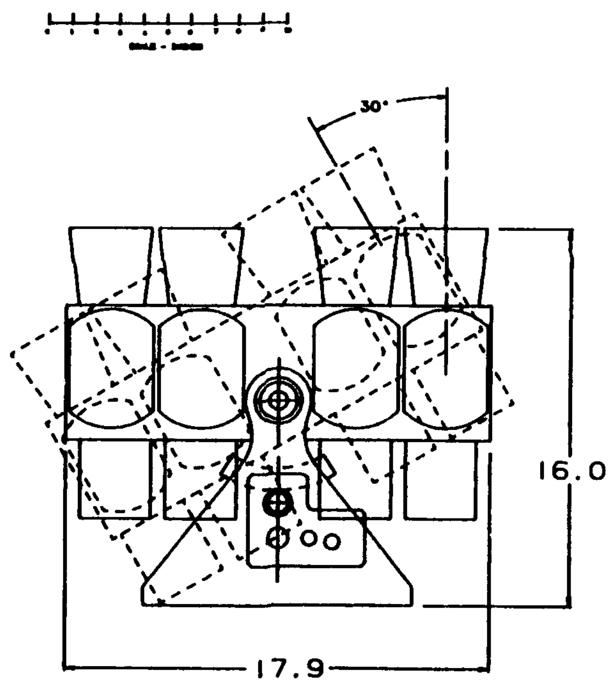
SCAN FOUR UNITS ON SINGLE PIVOT

HIGH CG AND PIVOT HEIGHT
FOUR INDIVIDUAL MODULES FOR EASIER ALIGNMENT
DOES NOT DEPEND ON MOUNT ISOLATION FROM THE SPACECRAFT

HIROIG

HIGH RESOLUTION OZONE IMAGER





DATA PROCESSING UNIT

D. J. MABRY

Dan Mabry
17 February 1993

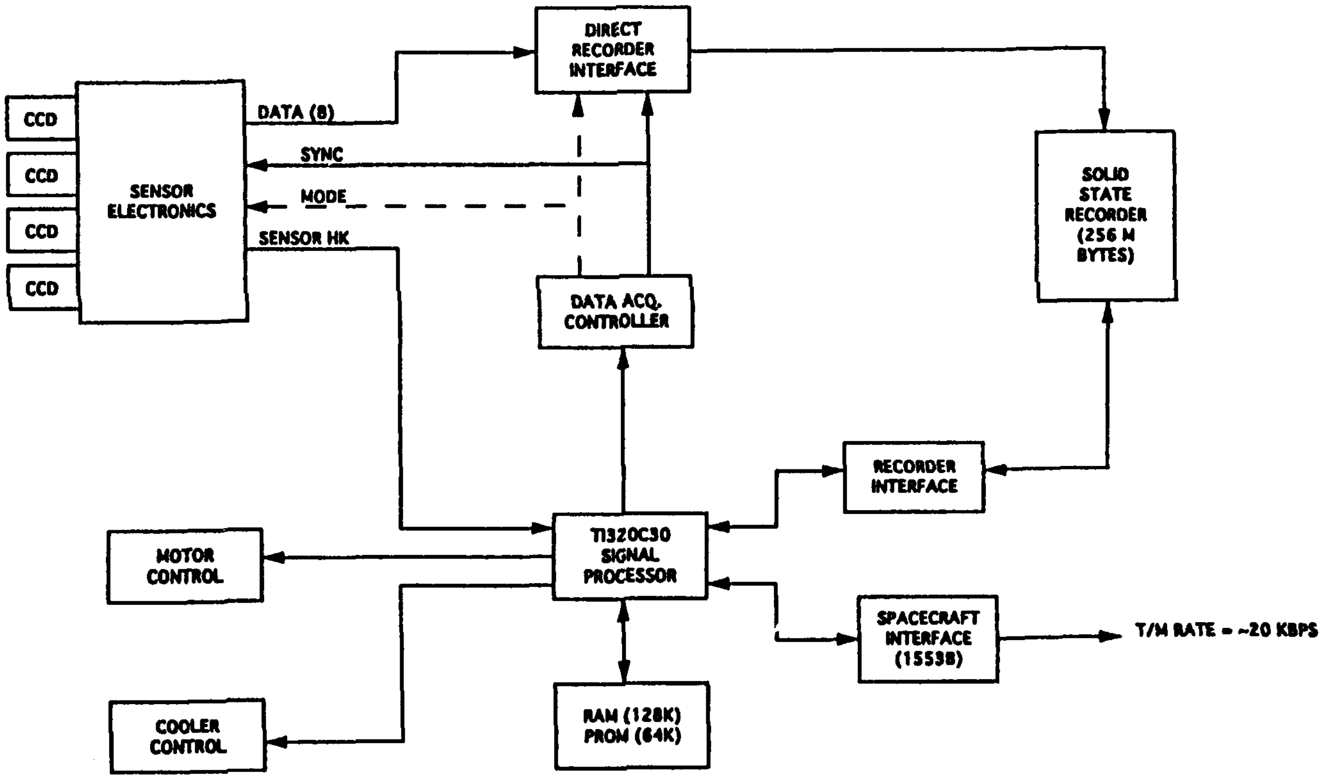
HIROIG DPU Requirements

The HIROIG Data Processing Unit (DPU) should provide capabilities to:

- accept images of 180 x 260 pixels (12 bits/pixel) from 4 imagers simultaneously at a frame rate of 7 images/second (15.7 Mbits/sec)
- provide storage on-board for 2 minutes of continuous image acquisition (225 Mbytes)
- provide data processing capabilities to reduce 225 Mbyte recorder content to fit within 100 Mbits/orbit telemetry allocation
- provide a "low noise" mode of operation during image exposure
- provide controls for coolers and motor(s). Accept, compile, and monitor cooler, motor, CCD, and power supply housekeeping data
- provide protected command interface with spacecraft, including capabilities for modifying flight software or table data

Dan Mabry
17 February 1993

HIROIG DPU Overview



Dan Mabry
17 February 1993

HIROIG DPU Modes

- Exposure Mode
  - Interleaved CCD images pass directly from signal conditioning electronics to recorder under hardware control
  - Processing electronics operate in "low noise" mode to reduce recorded image contamination
- Housekeeping Mode
  - Processing electronics become active for ~1 msec every 140 msecs while CCD image is transferred between active and masked area
  - Operations performed are cooler/heater monitoring, image header and trailer generation, recorder memory management
  - Software algorithms in conjunction with knowledge of available recorder space and acquisition parameters determine whether next mode is Exposure or Processing

Dan Mabry
17 February 1993

HIROIG DPU Modes (continued)

- Data Processing Mode
  - CCD data acquisition suspended during data processing
  - Primary function: "reduce" 225 Mbytes of recorder images to fit into 1 or more telemetry orbits (100 Mbits/orbit)
  - For non-recurring observations, recorder data can be minimally compressed and telemetered over several orbits
  - For recurring observations, compression factor (CF) of 20 is needed to empty recorder for next observation. Compression algorithms are being evaluated.

Dan Mabry
17 February 1993

HIROIG DPU Theory of Operation

- Ground command specifies look direction, start time and duration for observation

- DPU points imagers via motor controls, then waits for start of observation while monitoring housekeeping data

- DPU programs Data Acquisition Controller when observation time arrives, then the DPU toggles between Exposure and Housekeeping modes while images pass to recorder

- At end of exposure, Processing mode is entered to begin data compression and telemetry creation

Dan Mabry
17 February 1993

HIROIG Solid State Recorder

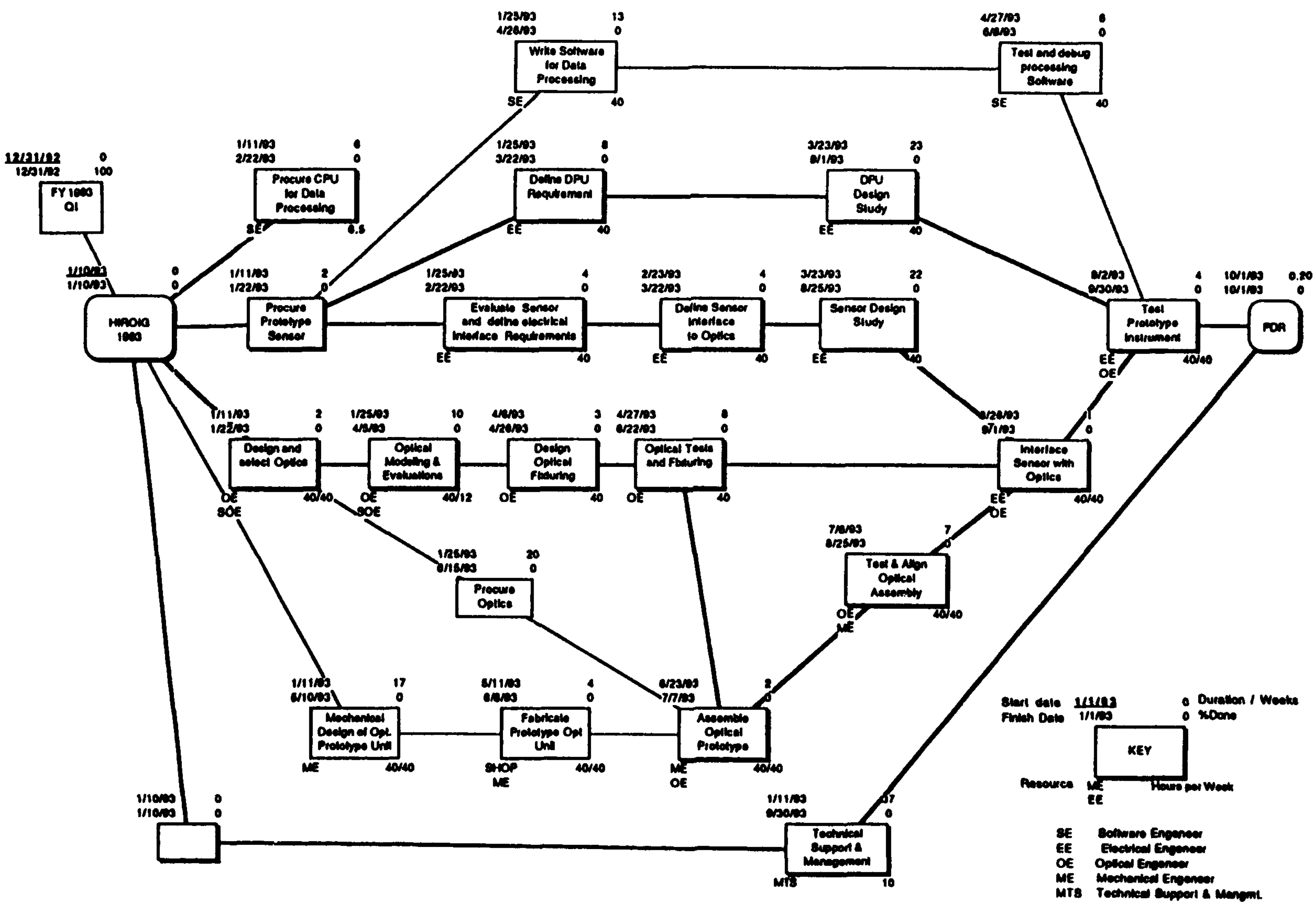
Model:	SEAKR Engineering SESSM - 1.9GR
Storage, Megabits:	1.9
Size, inches:	10 x 6.8 x 6.7
Data Channels:	8 bit parallel (input/output)
	serial control
Data Rates:	
Input Data:	25 Mbps
Output Data:	25 Mbps
Control:	125 Kbps
Input Voltage:	22 VDC to 36 VDC
Power:	
Standby:	5.75 Watts
Operational:	< 15 Watts
Bit Error Rate:	< 1 x 10E-10

MANAGEMENT AND SCHEDULES

J. A. Stein

OVERVIEW

1. PROJECT SCHEDULE
2. PROJECTED FUNDING REQUIREMENT
3. FUNDING ALLOTMENT BY ENGINEERING CATEGORY
4. PROJECTED SPENDING RATE & EXPENDITURES TO DATE



HIGH RESOLUTION OZONE IMAGER (HIROIG)
PROTOTYPE SYSTEM SCHEDULE

MANPOWER ALLOTMENT BY ENGINEERING CATEGORY (Man Weeks)
For Quarters 2 to 4 FY 1993

OPTICAL ENGINEERING	50
MECHANICAL ENGINEERING	44
ELECTRICAL ENGINEERING	49
SOFTWARE ENGINEERING	20
SCIENTIFIC STUDIES	30
MECHANICAL FABRICATION	8
MANAGEMENT	10

PROJECTED FUNDING REQUIREMENT

PRELIMINARY STUDIES IN FIRST QUARTER OF FY 1993	$ 76,300
PROJECTED LABOR FOR REMAINING FY 1993	$616,200
PARTS AND MATERIAL	$110,000
TOTAL PROJECTED COST FOR FY 1993	$802,500

THE AEROSPACE CORPORATION
Space and Environment
Technology Center

HIROIG
System Requirement Review

Feb. 17, 1993
Joe Stein

HIROIG LABOR COST SCHEDULE FY 1993

Starting	Plan Costs	Plan Income	Actual Costs	Actual Income	Ending	Plan Cumulative	Actual Cumulative
12/1/92	76300.00	0.00	76300.00	0.00	1/1/93	-76300.00	-76300.00
1/1/93	54514.36	0.00	40400.00	0.00	2/1/93	-130814.36	-116700.00
2/1/93	81525.11	0.00	0.00	0.00	3/1/93	-212339.46	-116700.00
3/1/93	98022.85	0.00	0.00	0.00	4/1/93	-310362.31	-116700.00
4/1/93	92824.95	0.00	0.00	0.00	5/1/93	-403187.26	-116700.00
5/1/93	74293.79	0.00	0.00	0.00	6/1/93	-477481.05	-116700.00
6/1/93	60348.42	0.00	0.00	0.00	7/1/93	-537829.47	-116700.00
7/1/93	60249.54	0.00	0.00	0.00	8/1/93	-598079.01	-116700.00
8/1/93	60194.24	0.00	0.00	0.00	9/1/93	-658273.25	-116700.00
9/1/93	34228.34	0.00	0.00	0.00	10/1/93	-692501.59	-116700.00
10/1/93	0.00	0.00	0.00	0.00	11/1/93	-692501.59	-116700.00

THE AEROSPACE CORPORATION
Space and Environment
Technology Center

HIROIG
System Requirement Review

Feb. 17, 1993
Joe Stein

HIROIG TOTAL COST SCHEDULE FY 1993

Starting	Plan Costs	Plan Income	Actual Costs	Actual Income	Ending	Plan Cumulative	Actual Cumulative
12/1/92	76300.00	0.00	76300.00	0.00	1/1/93	-76300.00	-76300.00
1/1/93	143687.34	0.00	40400.00	0.00	2/1/93	-219987.34	-116700.00
2/1/93	81028.90	0.00	0.00	0.00	3/1/93	-301016.24	-116700.00
3/1/93	113138.89	0.00	0.00	0.00	4/1/93	-414155.13	-116700.00
4/1/93	102019.57	0.00	0.00	0.00	5/1/93	-516174.70	-116700.00
5/1/93	77280.70	0.00	0.00	0.00	6/1/93	-593455.40	-116700.00
6/1/93	63219.81	0.00	0.00	0.00	7/1/93	-656675.22	-116700.00
7/1/93	58840.31	0.00	0.00	0.00	8/1/93	-715515.53	-116700.00
8/1/93	52757.72	0.00	0.00	0.00	9/1/93	-768273.25	-116700.00
9/1/93	34228.34	0.00	0.00	0.00	10/1/93	-802501.59	-116700.00
10/1/93	0.00	0.00	0.00	0.00	11/1/93	-802501.59	-116700.00

TECHNOLOGY OPERATIONS

The Aerospace Corporation functions as an "architect-engineer" for national security programs, specializing in advanced military space systems. The Corporation's Technology Operations supports the effective and timely development and operation of national security systems through scientific research and the application of advanced technology. Vital to the success of the Corporation is the technical staff's wide-ranging expertise and its ability to stay abreast of new technological developments and program support issues associated with rapidly evolving space systems. Contributing capabilities are provided by these individual Technology Centers:

Electronics Technology Center: Microelectronics, solid-state device physics, VLSI reliability, compound semiconductors, radiation hardening, data storage technologies, infrared detector devices and testing; electro-optics, quantum electronics, solid-state lasers, optical propagation and communications; cw and pulsed chemical laser development, optical resonators, beam control, atmospheric propagation, and laser effects and countermeasures; atomic frequency standards, applied laser spectroscopy, laser chemistry, laser optoelectronics, phase conjugation and coherent imaging, solar cell physics, battery electrochemistry, battery testing and evaluation.

Mechanics and Materials Technology Center: Evaluation and characterization of new materials: metals, alloys, ceramics, polymers and their composites, and new forms of carbon; development and analysis of thin films and deposition techniques; nondestructive evaluation, component failure analysis and reliability; fracture mechanics and stress corrosion; development and evaluation of hardened components; analysis and evaluation of materials at cryogenic and elevated temperatures; launch vehicle and reentry fluid mechanics, heat transfer and flight dynamics; chemical and electric propulsion; spacecraft structural mechanics, spacecraft survivability and vulnerability assessment; contamination, thermal and structural control; high temperature thermomechanics, gas kinetics and radiation; lubrication and surface phenomena.

Space and Environment Technology Center: Magnetospheric, auroral and cosmic ray physics, wave-particle interactions, magnetospheric plasma waves; atmospheric and ionospheric physics, density and composition of the upper atmosphere, remote sensing using atmospheric radiation; solar physics, infrared astronomy, infrared signature analysis; effects of solar activity, magnetic storms and nuclear explosions on the earth's atmosphere, ionosphere and magnetosphere; effects of electromagnetic and particulate radiations on space systems; space instrumentation; propellant chemistry, chemical dynamics, environmental chemistry, trace detection; atmospheric chemical reactions, atmospheric optics, light scattering, state-specific chemical reactions and radiative signatures of missile plumes, and sensor out-of-field-of-view rejection.